STRATEGIC & PRACTICAL USE OF REMOTE SENSING IN EMERGENCY MANAGEMENT (SPURS-EM)
PROJECT FINAL REPORT

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FOREWORD

EMD is pleased to introduce this document, the Strategic & Practical Use of Remote Sensing Emergency Management (SPURS-EM) Project Final Report. The development of this report was the result of a collaborative partnership with the Washington Emergency Management Division (EMD), University of Washington (UW), and the Western Disaster Center (WDC). The information contained herein was provided by team members from these organizations who were also involved in the review and edit process.

In 2002, the National Aeronautics and Space Administration (NASA) awarded a grant to EMD to investigate the use of moderate-resolution satellite imagery in emergency management. The project entitled, "*Strategic and Practical Use of Remote Sensing in Emergency Management (SPURS-EM)",* was different than most satellite-remote sensing (SRS) projects in that it focused on the use of data products *before* an event (mitigation and preparedness), opposed to the more traditional approach of performing analysis *during* or *after* an event (response and recovery).

As an industry, Emergency Management has not yet fully embraced Geographic Information Systems (GIS) and Remote Sensing (RS) as essential tools. However, as Emergency Managers become more reliant on mapping and analysis of scientific and technical data, the perceived lack of value of GIS and RS is slowly giving way to greater demand and interest in these technologies.

SPURS-EM was very successful in influencing the perceptions of emergency managers in Washington State and opening their minds to new and exciting ways to leverage current technologies in their mission to protect the people and property of Washington State. This report will document the experiences of the SPURS-EM team over the 4-year span of the project, highlight significant accomplishments, discuss research findings, and offer insight into the improved use of SRS in emergency management.

<Signature>

Terrence M.I. Egan, Ed.D.
Principal Investigator

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The SPURS-EM project involved many organizations and individuals. We gratefully acknowledge those contributions and extend our gratitude to those listed here, as well as the many others who are not specifically listed by name. The Emergency Management Division SPURS-EM Team consisted of:

- Terry Egan, Ed.D. – Planning, Exercise & Training Unit Manager – Principal Investigator
- John Ufford – Planning, Analysis & Logistics Section Supervisor
- Allen Jakobitz – Science & Technology Program Manager – Project Manager
- Andrew Bohlander – Science & Technology Program Coordinator – Researcher / Liaison
- Jeff Parsons – Critical Infrastructure Program Manager – Integration Team Leader
- Jillian Nordstrom – Public Assistance Program Assistant – Education & Outreach
- Ferrucio Crocetti – Retired – Proposal Developer
- Ed Quarles – Retired – Product Development

For their tireless support, understanding, and willingness to educate, which were invaluable in guiding the project definition and product development, we thank the University of Washington SPURS-EM Team:

- Miles G. Logsdon, Ph.D. – Research Assistant Professor
- Robin J. Weeks, Ph.D. – Research Assistant Professor
- Leon Delwiche – Research Assistant
- Camille Russell – Research Assistant
- Jill Coyle – Research Assistant

Additional support and consultation was provided by:

- Richard Davies. – Western Disaster Center
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- Fernando Llamas – Washington Emergency Management Division
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EXECUTIVE SUMMARY

The Project Final Report is the final document produced for the *Strategic and Practical Use of Remote Sensing in Emergency Management (SPURS-EM)* project and seeks to document the history of the project, discuss lessons learned, and offer meaningful conclusions and recommendations that will help the remote sensing and emergency management communities work more effectively in the future. The Project Final Report also constitutes a project deliverable.

The SPURS-EM project was designed to assist in the transformation of *information* acquired via satellite observations into the *knowledge* that emergency managers must have in order to make informed strategic decisions. This project sought to integrate satellite remotely sensed data with other thematic data layers to assist in the emergency management decision-making process. Prior to the advent of the SPURS-EM project, Washington Emergency Management Division (EMD) was actively developing a program called the *Strategic Forecast Support System (SFSS),* which was designed to support the conduct of objective and scientific vulnerability. The project built upon the philosophy of the SFSS to enhance the accuracy and reliability of EMD hazard analysis products by improving the scientific basis upon which those analyses were performed.

The project began at a time when both the remote sensing and emergency management disciplines were undergoing significant change. Remote sensing, which was once primarily an activity of the military and scientific communities, is not a booming industry. The commercialization of satellite imagery thrust remote sensing into the mainstream. Emergency management has also experienced marked change since the 9/11 attacks, and the advent of the Department of Homeland Security. Although emergency management continues to operate based on the four phases (mitigation, preparedness, response and recovery), the new focus on homeland security has created many new missions and directives, many of which focus on man-made hazards (e.g. terrorism) and emergency response.

SPURS-EM was designed as a partnership between the academic and emergency management communities, with the primary project partners being EMD and University of Washington (UW). This unique partnership provided opportunities for members of two very different disciplines to learn from one another. EMD staff improved their skills in Geographic Information Systems (GIS) and remote sensing, while our project partners in academia gained an understanding of the principles of emergency management, and the wide array of activities that are involved in mitigation, preparedness, response and recovery.

This was an intensive research project that required extensive data collection and processing, the development of hazard analysis methodologies, and the transfer of knowledge to local emergency managers and the general public. The knowledge, skills and abilities gained through SPURS-EM contributed greatly to the enhancement of the EMD Science & Technology Program, and the modernization of mapping and analysis in the State Emergency Operations Center (EOC).

The SPURS-EM project was the first of its kind to be undertaken by EMD. The experiences and lessons learned through this effort resulted in many significant changes, some of which will have long-lasting effects. The project team realized the value of satellite imagery in emergency management, but also recognized some significant limitations to its use including timeliness of data, spatial resolution, processing requirements, and lack of expertise. Remote sensing was also recognized as a highly complex and challenging activity that currently requires knowledge, skills and abilities that are not traditionally found in emergency management.

Through this research, EMD gained valuable insight into the task of integrating SRS in emergency management. The project final report offers a series of recommendations to assist the remote sensing community in meeting the needs of emergency management, which include providing more timely access to high resolution data and expert interpretations, reducing processing requirements, and the development of hazard-specific mapping and modeling tools for use in hazard analysis.

EMD is grateful for the opportunity to work with NASA and our colleagues in academia, and the public and private sectors that helped make the SPURS-EM project such a success. We look forward to participating in future endeavors with our new partners and anxiously await the development of new and innovative remote sensing tools and services that will serve the emergency management community and EMD in our mission to protect the people, property, economy and environment of Washington State.

PROJECT DISCUSSION

Project Proposal

When life and property are at risk from both natural and man-made disasters, the transformation of *information* into *knowledge* is the most effective tool that emergency managers may have. The SPURS-EM project was designed to assist in the transformation of *information* acquired via satellite observations into the *knowledge* that emergency managers must have in order to make informed strategic decisions. This project sought to integrate satellite remotely sensed data with other thematic data layers to assist in the strategic forecast of disaster probabilities and test scenario response for decision-making purposes (Project Proposal, 2001, 3).

At the time the project began, Emergency Management as an industry was reluctant to embrace current geospatial technologies and the use of SRS was perceived as a significant departure from common mission-oriented activities, such as planning and exercises. The Remote Sensing discipline was also in a state of flux with many new data products and applications still under development. Datasets were largely unavailable and did not function well with commercial off-the-shelf Geographic Information Systems (GIS) applications. In the years following the start of the SPURS-EM project, both industries have experienced both minor and major changes that significantly influenced the course of the project.

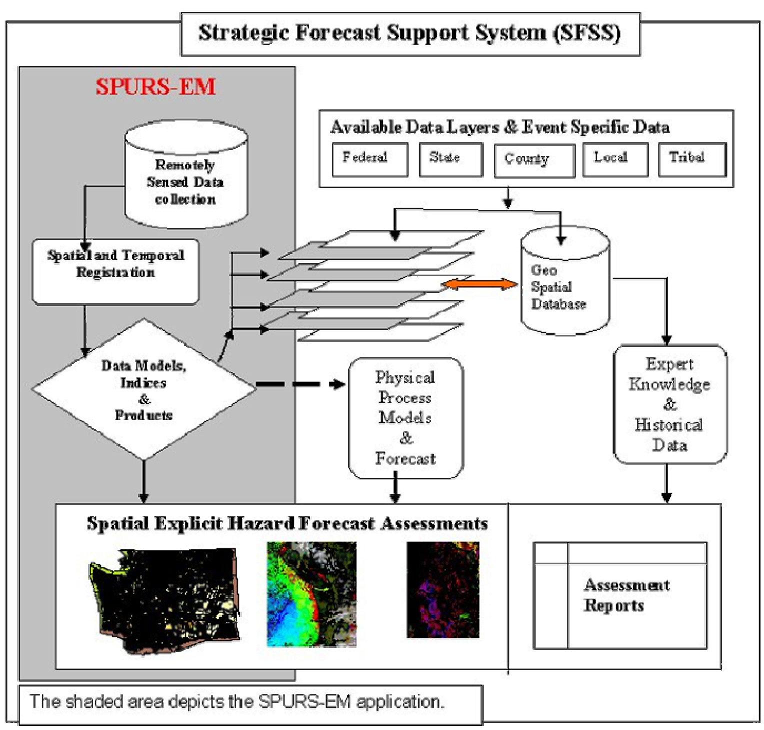
In April 2001, NASA issued BAA-01-OES-01, a Broad Agency Announcement (BAA) focusing on "opportunities for state, local, regional and tribal governments to utilize NASA and commercially developed data and capabilities in operations and decision support" (NASA BAA-01-OES-01, 2001). The BAA solicited projects that would utilize geospatial information derived from activities sponsored by the Earth Science Enterprise (ESE) of the National Aeronautics and Space Administration (NASA), commercial data, data products and services, or a combination of NASA/ESE and commercial capabilities. The BAA sought to improve decision-making and policy formulation in the operations of state, local, regional and tribal governments. The announcement reflected the belief of ESE that the evolving results of its Earth science investments, data and expertise from the U.S. commercial sector, provide significant opportunities to benefit the governance and economy of the nation. It anticipated that these projects would be *integrated applications partnerships* that would include all the elements for an operational solution; e.g., data and product supply, data processors, government departments and the ultimate end user or decision-maker.

At the time, EMD was developing its hazard analysis and GIS capabilities, with a focus on strategic forecasting of natural hazards and their associated risks. EMD recognized the NASA grant as an excellent opportunity to extend the use of spatial information in the assessment of hazards risks and vulnerabilities, establish and strengthen partnerships with the scientific community, and expand GIS capabilities to include Remote Sensing. EMD identified the University of Washington as a potential project partner and developed a strong proposal to investigate the use of moderate-resolution satellite imagery in emergency management. The proposal was approved by NASA, and the SPURS-EM project kicked off in June 2002.

Project Scope

The SPURS-EM project focused on the integration of moderate-resolution SRS data products in hazards analysis and strategic forecasting of risk. The EMD mission is "to minimize the impacts of emergencies and disasters on the people, property, environment, and the economy of Washington State." Central to this mission, is the process of identifying and analyzing potential hazards, risks and vulnerabilities. The SPURS-EM concept contributed directly to the EMD mission by providing more accurate and in-depth analysis of natural hazards and their distribution over space and time.

Figure 1: EMD Strategic Forecast Support System



Source: Washington Emergency Management Division

Prior to the advent of the SPURS-EM project, EMD was actively developing a program called the *Strategic Forecast Support System (SFSS)* (Figure 1), which was designed to support the conduct of objective and scientific vulnerability analysis of all hazards identified in the Washington State Hazard Identification and Vulnerability Assessment (HIVA). The SFSS sought to integrate proven technologies, such as Geographic Information Systems (GIS); hazard-specific applications, such as HAZUS and GeoMac; as well as the Internet and other available tools.

EMD identified all the hazards in the state and conducted risk assessments for each individual hazard. However, vulnerability analyses were not being performed because EMD lacked the requisite scientific tools and technical expertise to conduct the analyses. The Director's charge to the agency was to develop the tools and expertise to scientifically determine the likelihood of hazard events (Project Proposal, 2003).

SPURS-EM was different from other SRS applications in that of the four phases of emergency management (mitigation, preparedness, response and recovery) this project's goal was to evaluate the use of SRS in the mitigation and preparedness phases. By design, this project did not address the strategic and practical use of remote sensing in the recovery and response phases. While there are numerous applications for remotely sensed data in all aspects of emergency management, pre- and post-disaster monitoring of infrastructure and economic impact receive the greatest attention. The SPURS-EM program and the product research and development team targeted the monitoring of the natural system infrastructure and its economic consequences during the mitigation and preparedness phases of emergency management. This direction for the program placed an emphasis on EMD's role as coordinators of plans and assistance to regional and local emergency managers (Logsdon, 2005).

In order to understand the Earth as a completely integrated system, we need long-term measurements of its various environments at specific temporal, spectral and spatial intervals (Herring, 1998, 2). SRS data is particularly capable of providing these types of measurements over wide geographic areas. The SPURS-EM project focused on the use of SRS data to identify natural hazards, specifically wildfires, floods, and droughts, prior to their occurrence. To understand and examine these hazards, it was necessary to consider the types of data (e.g. vegetation, temperature), the format of the data (e.g. TIFF, HDF), the spatial resolution (e.g. 250m, 1km), and the temporal resolution (e.g. 8-day, 16-day). The geographic scope of the SPURS-EM project was the geopolitical boundary of Washington State. This included the marine waters of Puget Sound and the Pacific Ocean. The SPURS-EM Team chose to focus the analyses on relatively small zones called "ecoregions" because small-scale (large area) analyses are often problematic.

SPURS-EM involved many people, agencies and organizations representing federal, state, and local government, academia, and the private sector. EMD assigned project focus areas, research, activities and deliverables to a variety of working groups, which consisted of individuals with specific skills, experience and perspectives that were critical to the success of the group mission. These groups included the:

- Product Team
- Integration Team
- Development Team
- Evaluation Team

The *Product Team* consisted of Miles Logsdon, Ph.D., Robin Weeks, Ph.D., Leon Delwiche, Sara Rodda and Jill Coyle from the University of Washington and Andy Bohlander from EMD. The Product Team focused on the research and development of SPURS-EM products, testing of research hypothesis, and experimentation with various indices in hazard analysis.

The *Integration Team* consisted of Jeff Parsons, Allen Jakobitz, Ed Quarles, Andy Bohlander, Ute Weber, and Jill Nordstrom from EMD. The Integration team focused on identifying key business functions and information needs of emergency managers that could be supported by SPURS-EM products.

The *Development Team* consisted of Jeff Parsons, Allen Jakobitz, Andy Bohlander, Ute Weber, and Jill Nordstrom from EMD. The Development Team focused on the design and development of delivery mechanisms for transmitting SPURS-EM products to users in the emergency management community.

The *Evaluation Team* consisted of Richard Davies from the Western Disaster Center and Bob Freitag from the UW Institute for Hazard Mitigation, Planning and Research (IHMPR). The Evaluation Team provided feedback to all teams throughout the course of the project.

RESEARCH & DEVELOPMENT

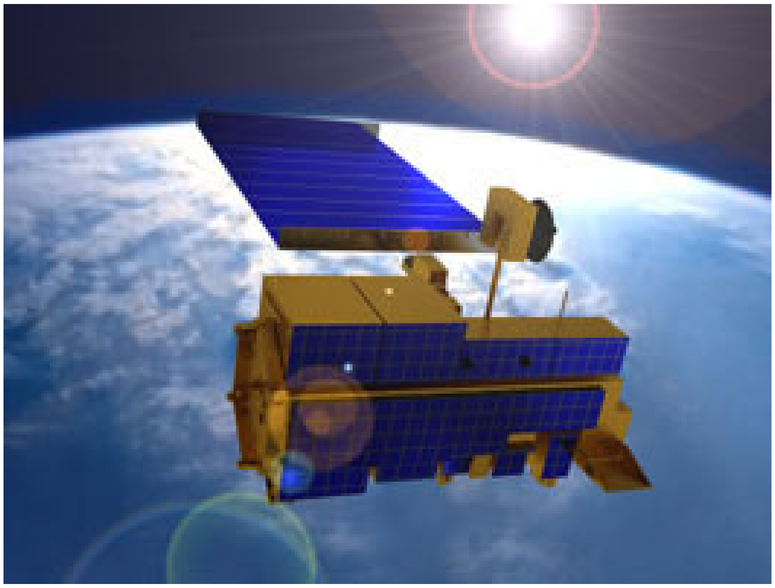
Data Availability and Applications

This task initially focused on the collection of relevant remotely sensed satellite image data for the SPURS-EM project related to the production of a general adaptive classified landcover dataset, and monthly indices that characterized aspects of the biophysical condition of the geographical extent of Washington State. Metadata for these data were assembled, assessed for quality where possible, and then cataloged when used in the SPURS-EM Metadata Browser application (see Project Deliverables).

A number of different remotely sensed data types, sensors, and platform options were considered in the initial stages of this project. While not explicitly called for by this contract, the UW Product Team provided various training sessions on both the conceptual and applied aspects of Geographic Information Systems (GIS) and multi-spectral remotely sensed datasets. EMD has a statewide responsibility for maintaining current information useful in hazard planning and mitigation. The Product Team training sessions were useful in determining spatial and temporal data needs and collection methods.

Early in the project it was determined that SPURS-EM would utilize NASA's Earth Observing System (EOS) as the primary source of satellite remote sensing (SRS) data. The EOS is composed of a series of satellites that provide long-term global observations of the land surface, biosphere, solid Earth, atmosphere and oceans (NASA EOS, 2005). Given that most EOS observations focus on natural phenomenon, it seemed appropriate that we focus our efforts on the natural hazards that affect our state. While wildland fires and droughts were obvious choices, we also sought to investigate more obscure hazards such as oil spills, avalanches, landslides, and mass bio-burial (a hazard that affectionately became known as "dead cows"). The bio-burial hazard focused on identifying areas in the state that would be appropriate for disposing of a large number of animal carcasses following a mass animal casualty event. Focusing on the natural hazards helped us in determining what platforms and data products would best meet our needs.

Figure 2: Artist Rendition of the MODIS instrument

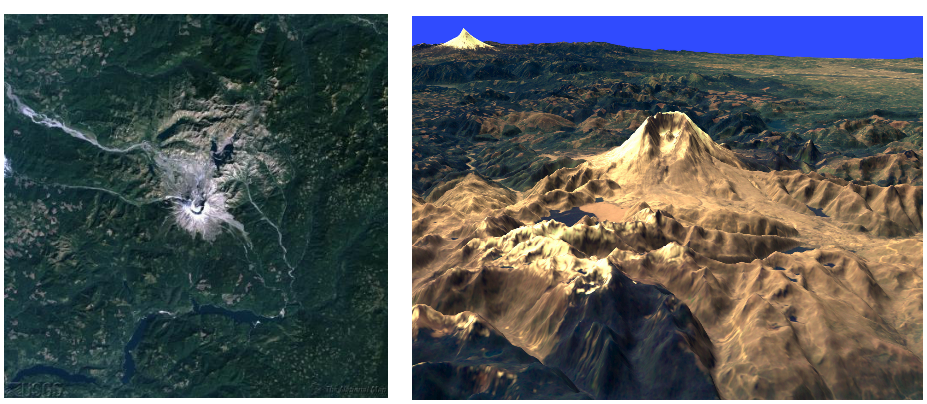


Source: National Aeronautics and Space Administration (NASA)

The SPURS-EM team assessed five indices for application in the mitigation and preparedness phases of emergency management. Selected indices had a historical time series and all indices were in the form of geospatial datasets. The team investigated the following instruments/data types, some of which were recommended in the original NASA proposal.

Landsat ETM (Enhanced Thematic Mapper): The team reviewed Landsat data as a general landcover dataset for the Puget Sound region in coordination with the University of Washington PRISM project (Figure 3).

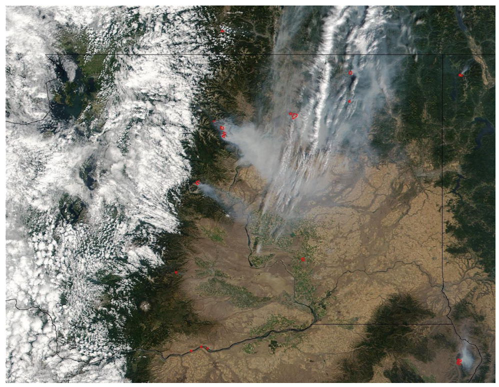
Figure 3: Landsat Images of Mount Saint Helens, Washington



Source (left): United States Geological Survey (USGS) (9/11/ 2004)
Source (right): NASA Goddard Space Center

<u>*MODIS (Moderate Resolution Imaging Spectroradiometer):*</u> The Product Team primarily depended upon the MODIS Terra dataset for the majority of the derived products, including the ecoregion statistics, statewide images, and risk assessment reports. After considering data accessibility, archiving and future data availability, the Product Team determined that MODIS offered the greatest statewide coverage for all natural hazard applications (Figure 4).

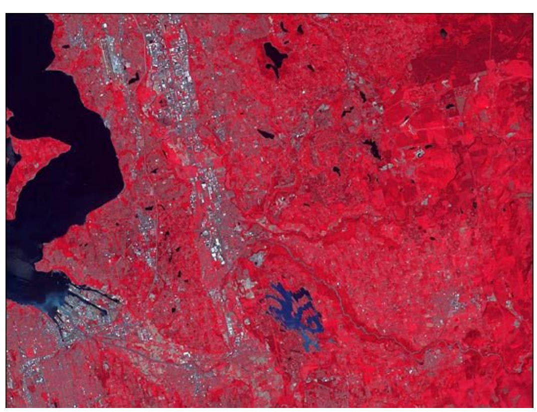
Figure 4: MODIS Natural Color Image of Fires in the Pacific Northwest (8/20/2001)



Source: Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC

<u>*ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer):*</u> The Product Team determined that the ASTER archiving and accessibility system was not user-friendly, and would have required much more work to create the derived indices necessary for emergency management. While ASTER data may prove useful to emergency management in the future, the MODIS data products were more reliable and dependable (Figure 5).

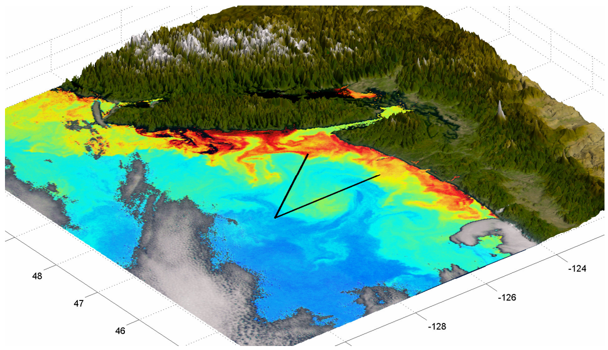
Figure 5: ASTER Image of Tacoma, Washington (2/28/2001)



Source: NASA/GSFC/MITI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team and Paul Morin, University of Minnesota

<u>*SeaWiFS (Sea-viewing Wide Field-of-view Sensor):*</u> SeaWiFS data provided an index for ocean color and ocean productivity. However, uncertainty regarding the future availability of SeaWiFS data, and the availability of the MODIS Aqua data, the Product Team discontinued the use of the SeaWiFS data after the first year and moved entirely to the MODIS Aqua ocean color products (Figure 6).

Figure 6: SeaWiFS Image of the Coastal Margin of Vancouver Island and Washington



Source: Brandon Sackmann, Doctoral Candidate, University of Maine (10/2/2004)

<u>*SAR (Synthetic Aperture Rader):*</u> SAR was the only source of radar data evaluated. After assessing its background, the Product Team concluded that working with SAR data for quality control would exceed the scope of SPURS-EM. SAR data had the fewest number of applications when the project was first evaluated and was eliminated from further processing after the first month of the project. The Product Team also evaluated the use of ScanSAR data and C-band data with 70-meter resolution for potential use in change detection and physical form mapping and determined that these data did not maintain the focus on mitigation and preparedness, but rather a potential for use in response to natural hazards.

Figure 7: Synthetic Aperture Radar (SAR) Image of Wenatchee, Washington

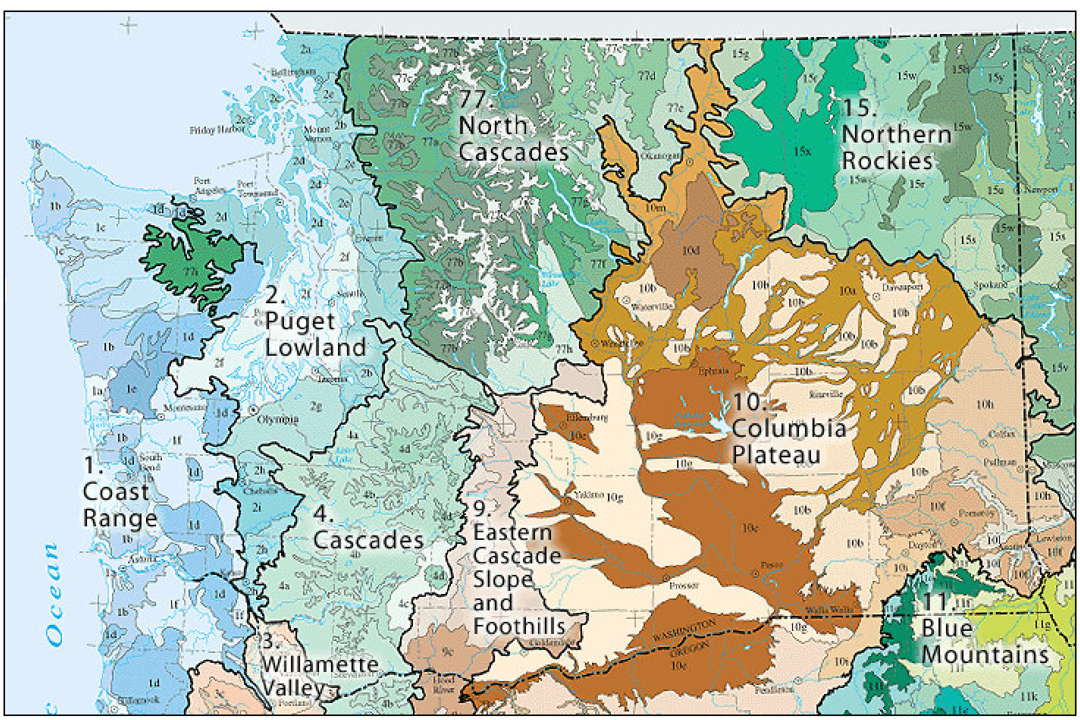
Source: NASA Jet Propulsion Laboratory

The SPURS-EM Team determined that three instruments would support the data acquisition phase: Landsat, the Moderate Resolution Imaging Spectroradiometer (MODIS), and the Advanced Very High Resolution Radiometer (AVHRR). The team considered issues of data availability, integrity, ease of use, processing requirements, and cost, and ultimately decided to use Landsat in the development of an adaptive landcover classification and MODIS and AVHRR to develop the time series and for hazards analysis.

Understanding Hazards over Space

After determining the availability of data products and applications, the team considered the geographic scope of the research. The team established the conceptual study area that encompassed all of Washington State but recognized that assessing risk over such a large area is quite cumbersome and the results are very coarse. To overcome the challenges involved when studying a large geographic area, the team elected to break the study area down into smaller, discrete regions (or zones) that would be suitable for analysis. The team concluded that the Level III Ecoregions provided by the Environmental Protection Agency (EPA), would provide suitable analysis zones (Figure 8).

Figure 8: Level III Ecoregions of Washington State



Source: U.S. Environmental Protection Agency

Ecoregions are defined as areas of relative homogeneity in ecological systems and their components. Factors associated with spatial differences in the quality and quantity of ecosystem components, including soils, vegetation, climate, geology, and physiography, are relatively homogeneous within an ecoregion. Ecoregions separate different patterns of human stresses on the environment and different patterns in the existing and attainable quality of environmental resources. They are an effective aid for inventorying and assessing national and regional environmental resources, for setting regional resource management goals, and for developing biological criteria and water quality standard (U.S. EPA, 2005). The Product Team determined that ecoregions would be highly effective in assessing ecosystem stability because their characteristics and boundaries are dependent on ecosystem variables.

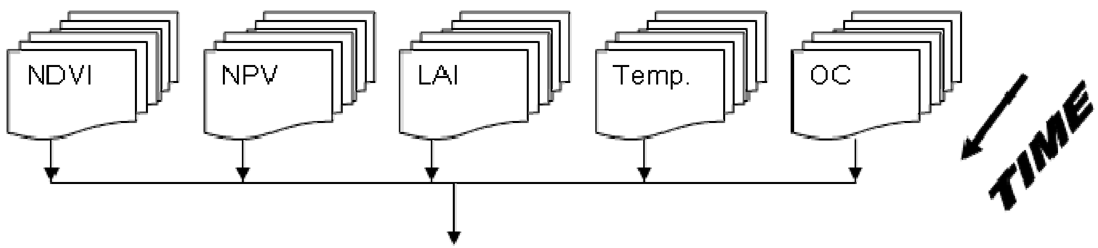
The determination to use ecoregions as hazard analysis zones was a turning point in the SPURS-EM project and significant for a number of reasons. First, ecoregions enabled us to conduct statewide hazard and risk assessments with adequate spatial resolution. Secondly, EMD staff developed a more fundamental understanding of how natural hazards occur and that the likelihood of a natural hazard occurring depends not only on geographic location, but also on environmental variables that affect ecosystem stability. Variables such as vegetation and land surface temperature generally exhibit specific characteristics before, during, and after a hazard event. The ecoregions helped us to understand those variations and how they relate to hazard occurrence.

Understanding Hazards over Time

"Risk" can be defined as the potential occurrence of unwanted adverse consequences to human life, health, property, and/or the environment. The estimation of risk is usually based on the expected value of the conditional probability of the event occurring, multiplied by the consequences of the event, given that it has occurred (Society of Risk Analysis). Analyzing risk in terms of probability necessitates that the spatial component, in other words how risk is distributed over space, be augmented by a temporal component that considers the distribution of risk over time. When the project was first envisioned, the team was unsure what role historical trends would play in hazard analysis. The team found historical data critical in hazard analysis and became the foundation for the monthly hazard analysis processes (UW Team Final Report).

The team determined that a *time series analysis* of historical data would yield valuable insight into the behaviors of ecosystem variables over time, thereby enhancing our ability to associate hazard events with ecosystem stability. Time series data sets consisted of historical imagery from 1981 through 2004 collected by the AVHRR instrument, and imagery collected by MODIS from 2000 through present. Three separate time series were developed for Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), and Ocean Color (OC). The Ocean Color time series is limited to the years 2000-2005 because these data are collected by MODIS and no other historical archives were available to supplement the MODIS archive (Figure 9).

Figure 9: Data Products – Time Series



Source: University of Washington

The team used ArcGIS desktop applications to integrate the spatial and temporal analysis components into a single analysis environment. ArcGIS is a collection of GIS software products that allows users to:

- Build powerful geoprocessing models for discovering relationships, analyzing data, and integrating data.
- Perform vector overlay, proximity, and statistical analysis.
- Generate events along linear features and overlay events with other features.
- Convert data to and from many formats.
- Build complex data and analysis models and scripts to automate GIS processes.
- Publish cartographic maps using extensive display, design, printing, and data management techniques (ESRI, 2005).

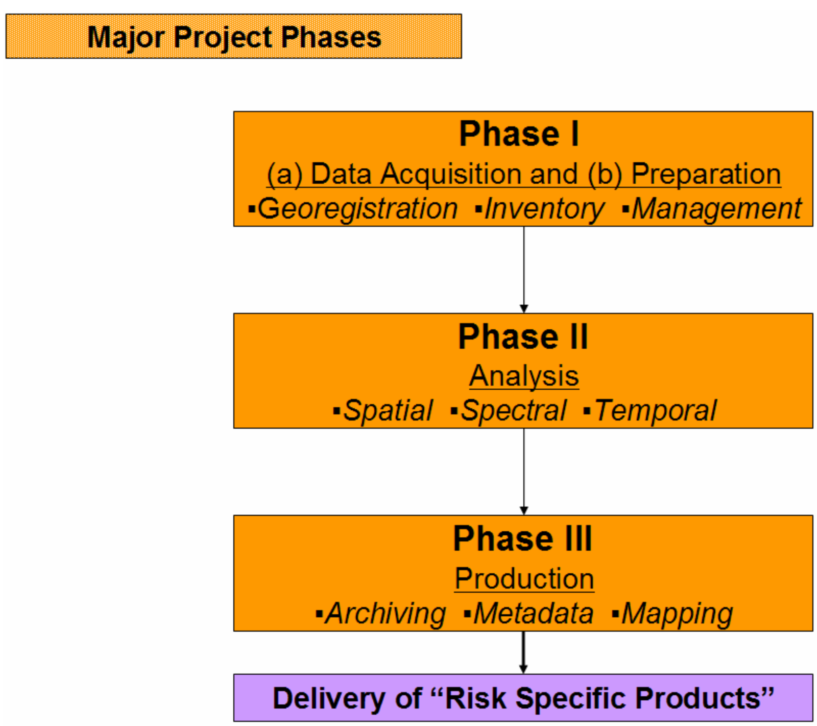
ArcGIS was the primary software application used in the SPURS-EM project and enabled the analyst to analyze data qualitatively (e.g. symbology) and quantitatively (e.g. zonal statistics), which proved to be a powerful combination. Qualitative analyses were useful in visualizing and identifying unique patterns and trends in the data that could contribute to an increased risk of hazard occurrence and was particularly useful in that it allowed the analyst to make observations at scales much larger than that of the ecoregions. Qualitative analyses focused more on identifying deviations from normalcy at the regional level and generally preceded quantitative analyses. Quantitative analyses investigated current vegetative and temperature conditions for all ecoregions, and identified ecoregions that were experiencing, or could potentially experience, variations that could cause system instability and increased risk of hazard occurrence. EMD GIS staff quickly realized the need for historical hazard datasets to support applications outside of SPURS-EM and began collecting other temporal geospatial datasets, including historical occurrence of fires, floods, and other natural hazards. These datasets support hazard analysis and risk assessment and are used during emergency operations.

Research Methodology

The SPURS-EM project tested a conceptual integration procedure that evaluated how image data and derived products could be combined with other static data layers in a GIS to test disaster probability scenarios and affect decision-making processes. Based on this conceptual framework, the team developed two scenarios to test the use of remote sensing in the decision making process for an "early alert analysis". The "early alert analysis" evolved from various investigations that targeted the role of EMD in providing strategic forecasts of hazards events. The Product Team designed scenarios to test not only how the early alert product could be produced but also how EMD staff could bring together different data layers to assist in making forecasts.

The research and development phase consisted of five primary tasks: Data Selection and Acquisition; Adaptive Landcover Classification; Generation of Image-derived Indices; Data and Product Assessment, and; Database Design and Implementation. Research and development was completed through three project phases: Data Acquisition and Preparation, Analysis, and Production (Figure 10).

Figure 10: SPURS-EM Major Project Phases



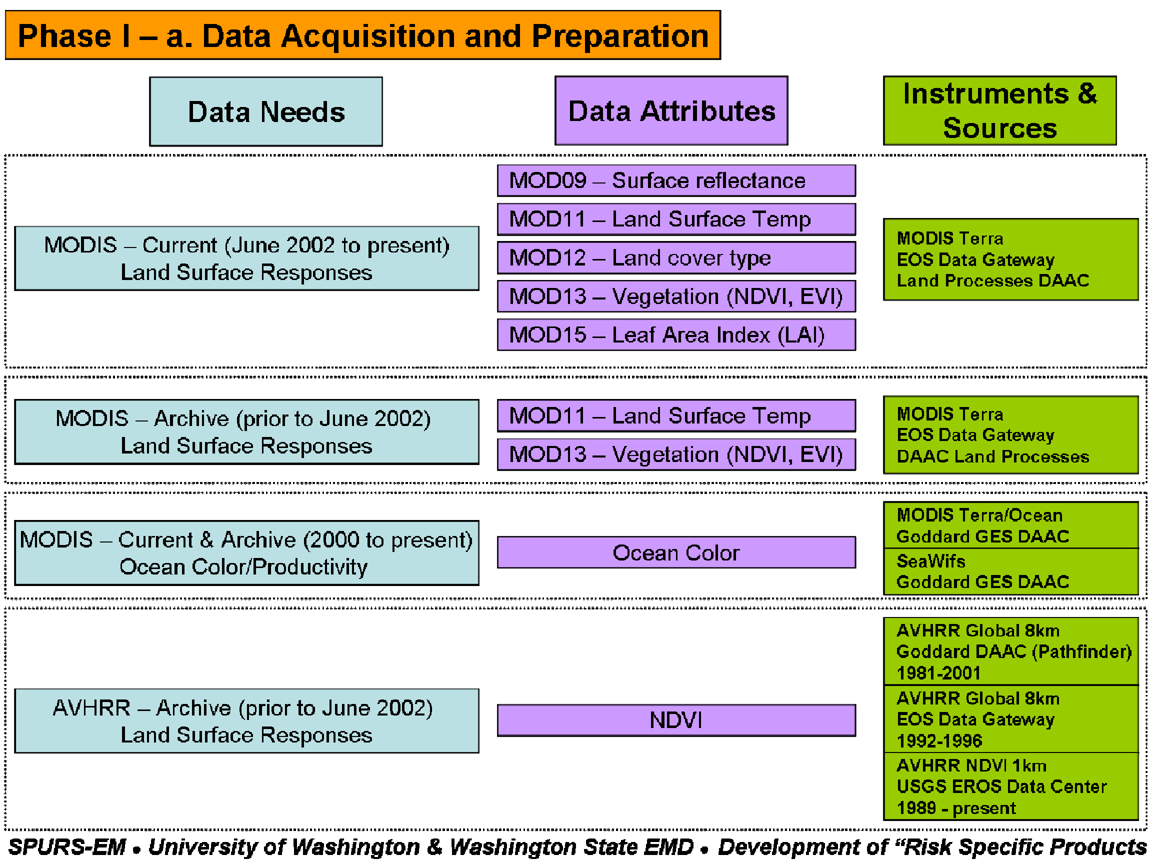
Source: University of Washington

Phase I: Data Preparation

MODIS Processing

The team discovered a wide variety of options were available (media and format) for ordering and downloading data. The team reviewed a number of these sites and determined that the Land Processes Distributed Active Archive Center (LP DAAC) best met the needs of our project. The LP DAAC was established as part of NASA's Earth Observing System (EOS) Data and Information System (EOSDIS) initiative to process, archive, and distribute land-related data collected by EOS sensors (LP DAAC 2005). The LP DAAC provided multiple opportunities for data acquisition including the Earth Observing System Data Gateway (EDG), the USGS Global Visualization Viewer (GloVis), and the MODIS Data Pool. The Earth Observing System Data Gateway (EDG) provided a convenient means of searching data archives and ordering data products and was the most applicable to the SPURS-EM project.

Figure 11: Data Acquisition Overview

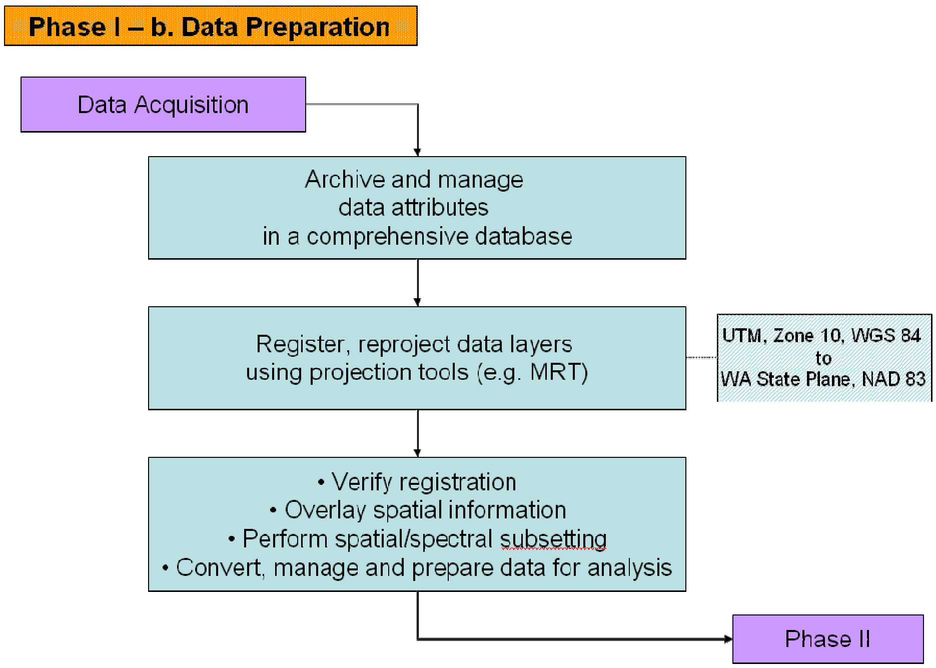


Source: University of Washington and Washington EMD

The EDG site provided efficient and user-friendly search capabilities that included search options such as: instrument type, dataset type, geographic area, date/time range, and additional options. Search time was generally very efficient with most searches requiring less than two minutes to complete. Search results were conveniently organized and a list of data granules indicated the data granule names, date/time of acquisition, and latitude/longitude center points. The ordering process was similar to an online shopping experience. The analyst added data products to a shopping cart and selected the desired format, delivery type, etc. The option to have data delivered via in file format via DVD was particularly useful in that it eliminated lengthy download times and provided a hardcopy backup for all datasets. The site offered a rapid turnaround time, with most data being delivered within one week of the order date. Data were also delivered via File Transfer Protocol (FTP), which provided a much faster turnaround time that averaged three days. The FTP process was costly in that it required significant bandwidth to support the transfer of files but was the delivery method of choice in many instances.

Once the analyst received the data, data preparation began. Data preparation involved assigning projections, georegistration, mosaicing of tiled images, and assigning file names to archive data, as shown in Figure 12. NASA and the USGS provided the MODIS Reprojection Tool (MRT) to support the data preparation process. Most "commercial off the shelf" software used for image processing and spatial data analysis do not accommodate the ISIN projection, which is the projection standard for Level-3 MODIS data products. The LP DAAC supported the development of the MRT, anticipating that the community of land processes data users would need special software tools for handling the Level-3 MODIS land data products that would be distributed in Hierarchical Data Format (HDF) and Integerized Sinusoidal (ISIN) projection. The analyst used the MRT to read data files in HDF format, specify geographic subsets, perform geographic transformations to different coordinate systems/cartographic projections, and write outputs to file formats other than HDF (e.g. GeoTIFF) (LP DAAC 2005).

Figure 12: Data Preparation Overview



Source: University of Washington and Washington EMD

Once the MRT had been installed, the analyst began the process of projection, georegistration, mosaicing, and archiving. The Terra satellite acquires data in separate swaths as it passes over the Earth's surface. Two individual swaths are required to create a single, full-coverage image of Washington State The analyst processed the swaths individually and used the MRT to mosaic them into a single image file, after which they were projected. The analyst assigned a datum of WGS 84 and a projection of UTM Zone 10 to all datasets in order to limit the potential for data loss in the projection process. The mosaicing process consists of the following steps:

- File Selection: choose the HDF files (swaths) you wish to mosaic
- Band Selection: choose the bands you wish to extract (e.g. LST_1km_Day)
- Datum: choose the datum of the output file (e.g. WGS84)
- Projection: choose the projection of the output file (e.g. UTM Zone 10)
- Output File Type: choosing the output file format (e.g. GeoTIFF)
- Output File Name: choose the output file name (e.g. mlst1km010303)
- Output File Location: choose the location of the output file

Once the images were mosaiced, the analyst had to verify the data, convert it to floating point (for analysis purposes), and "collapse" the data into rasters that represented "monthly datasets". The collapsing process supported the development of ecoregion statistics, as well as the time series analysis. The analyst completed the verification, conversion, and collapsing of datasets in the ArcMap environment. ArcMap is the central application in ArcGIS Desktop for all map-based tasks including cartography, map analysis, and editing (ESRI 2005).

The analyst opened the projected datasets in ArcMap, and applied a standard symbology to verify the data was valid and had been projected correctly. Once the symbology was applied, the analyst confirmed that (1) the projection was successful and the data aligned correctly with other spatially-referenced datasets, and (2) the data itself was validated by checking values and looking for data errors, such as noise and missing data. Washington State experiences significant cloud cover during some months, and these atmospheric effects can result in errors in the data. Noise refers to random or repetitive events that can obscure or interfere with the desired information and can result from a variety of causes that affect the value of the signal. Generally, if significant noise or other errors persisted in the data it was due to a technical error. The EDG homepage provided information regarding these, and other problems.

Following the verification of the data, the analyst converted each raster from integer to floating point data to enable the production of statistics that would later be used to investigate departures from the mean for individual indices and ecoregions. Once the data had been converted to floating point, the analyst "collapsed" the individual rasters into a single raster. MODIS collects data on 8-day, 16-day, and 30-day cycles. The majority of the data used in this project were 8-day; subsequently there were typically four individual rasters for any one month. The analyst referred to the date range, which is based upon the Julian day calendar, to determine which rasters to collapse for any one month. For example, the rasters for the month of June would fall between Julian days 151 and 181 for regular years, and 152 and 182 for leap years. The analyst then used the Raster Calculator and basic map algebra to calculate the maximum value for each cell based on the four total values from the original rasters. The following map algebra was applied:

Output Grid = max(ingrid1)(ingrid2)(ingrid3)(ingrid4)

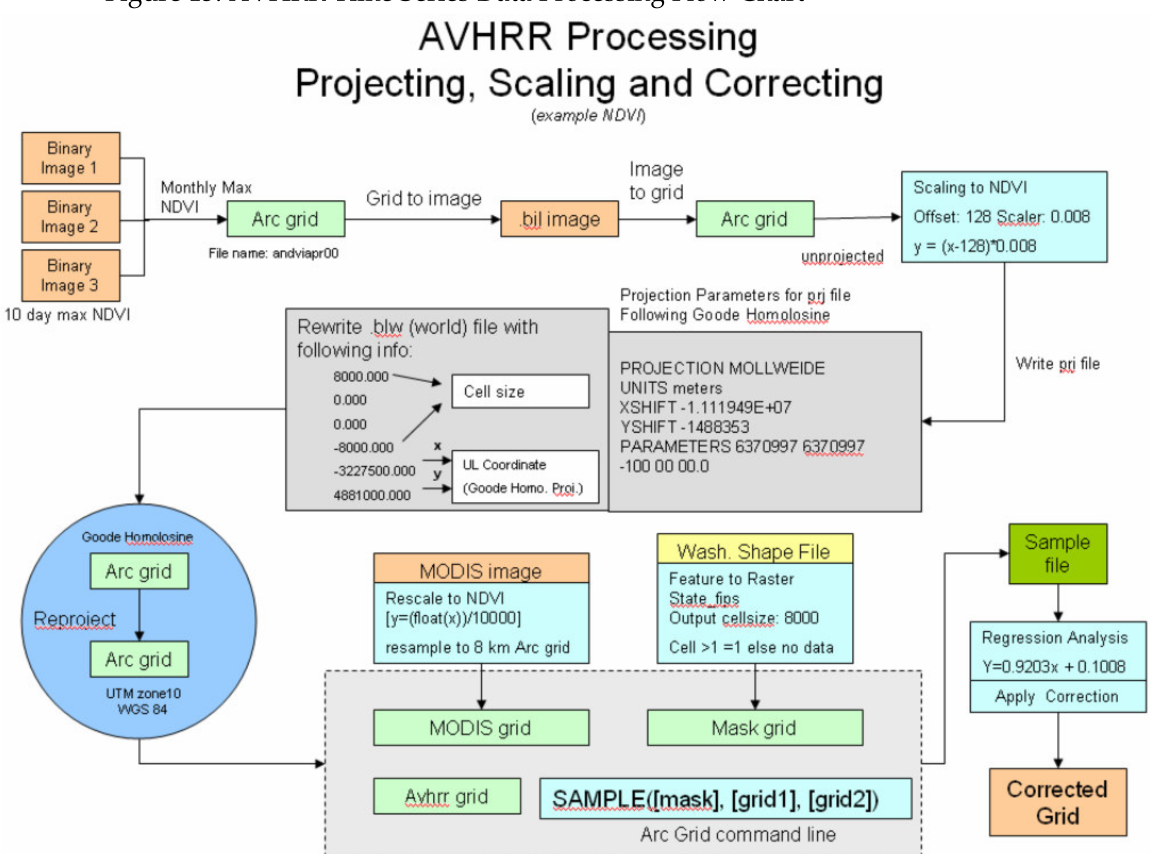
This equation produced an ESRI GRID with a spatial resolution of 1-kilometer resolution where each cell represented the maximum observed value for NDVI or LST for a specific date range (roughly 30 days).

The final step in preparing the MODIS data for analysis was the generation of zonal statistics for NDVI and LST. Zonal statistics are calculations of a statistic for each zone of a zone dataset based on values from another dataset called a value raster. A single output value is computed for each cell in each zone defined by the input zone dataset. In this case, the zone dataset was the Washington State Ecoregions, a polygon shapefile. The value raster was the output grid created during the collapse process, the cell values of which represented the maximum observed values for NDVI and LST for a given month. The analyst archived all zonal statistics for later use in quantitative analysis.

AVHRR Processing

The Product Team performed a linear regression analysis on the AVHRR/MODIS Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) Index, which consisted of months from 2000 and 2001 during which MODIS and AVHRR overlapped.

Figure 13: AVHRR Time Series Data Processing Flow Chart



Source: University of Washington & Washington EMD

Each regression, as shown in Figure 13, was applied to the appropriate AVHRR data set to calibrate it to the MODIS instrument. Time series data sets consisted of historical imagery from 1981 through 2004 collected by the AVHRR instrument and imagery collected by the MODIS in operation on the Terra platform from 2000 through present. AVHRR data acquisition and processing consisted of a 6-step process:

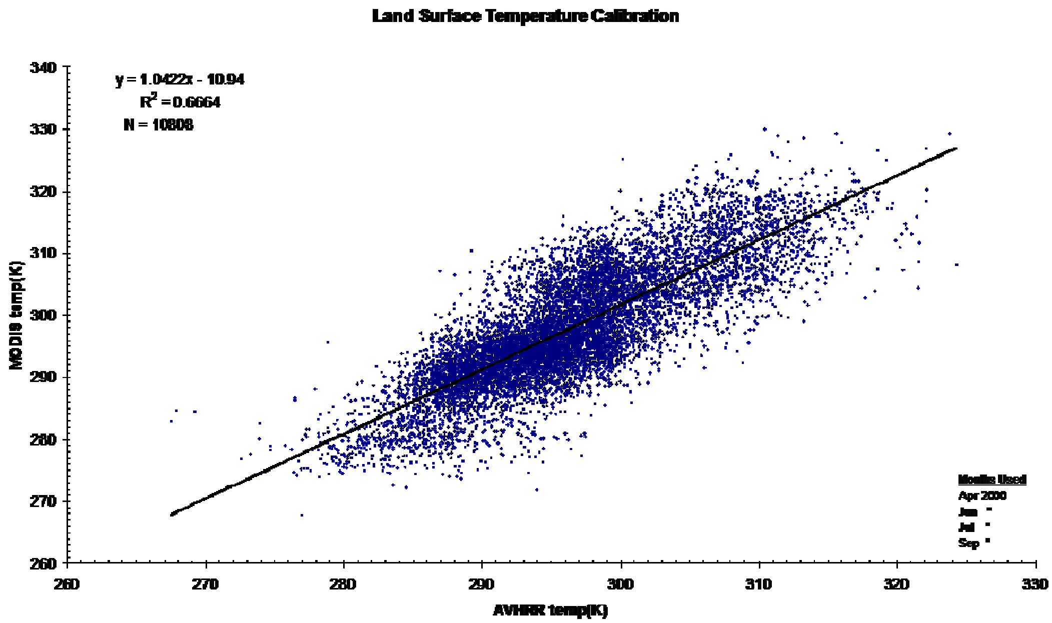
1. Download raw image files
2. Convert to grid as Monthly Max
3. Convert to image and write world file
4. Convert to grid and reproject
5. Clip to Washington State
6. Calibrate to MODIS

Original raw data consisted of a set of binary files (3 per month), each representing a 10-day period. The analyst converted each image to an unprojected grid and assigned a scale factor that scaled the data values for each cell to values that represented the index being used. For example, NDVI images were scaled such that each cell represented a number from -1 to +1, the standard scale for NDVI. The analyst then applied map algebra to calculate the monthly maximum for each cell over the 30-day period.

The Product Team then assigned a projection to each grid so that a regression could be performed between the AVHRR and MODIS data. A native projection of Goode Homolosine (native format) was assigned to each grid, which were then reprojected to UTM Zone 10 WGS84 (SPURS-EM project standard projection). The Product Team selected the project with a focus on minimizing data loss through the projection process.

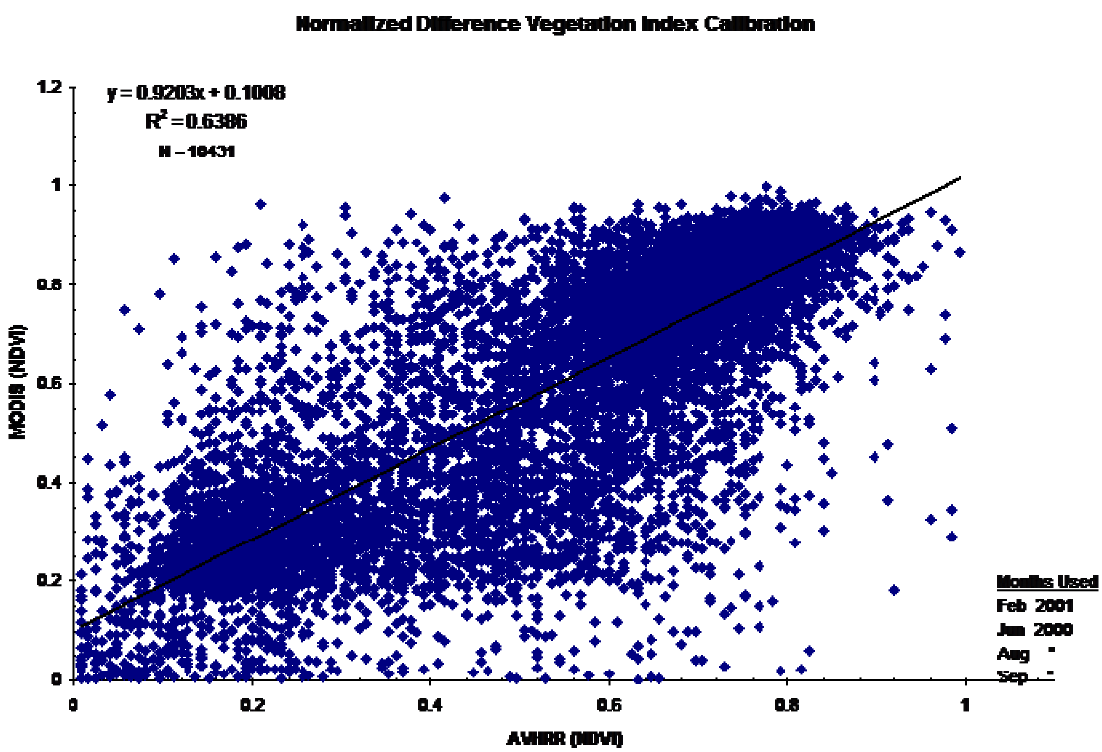
Following the projection, the Product Team rescaled MODIS and AVHRR datasets to establish a uniform spatial resolution of 1km, and then applied a mask to limit the extent of each dataset to the bounding coordinates of the study area (Washington State). The Product Team then performed a regression analysis ($Y = 0.9203x + 0.1008$) to create a seamless continuation between the historical AVHRR datasets and the current MODIS time series (see Figures 14 and 15). The Product Team found it necessary to perform a regression on spectral data prior to processing the indices and cited that the regression process was difficult due to the fact that AVHRR has a broader Infrared (IR) band than the MODIS instrument.

Figure 14: AVHRR Land Surface Temperature (LST) Calibration



Source: University of Washington

Figure 15: AVHRR Normalized Difference Vegetation Index (NDVI) Calibration



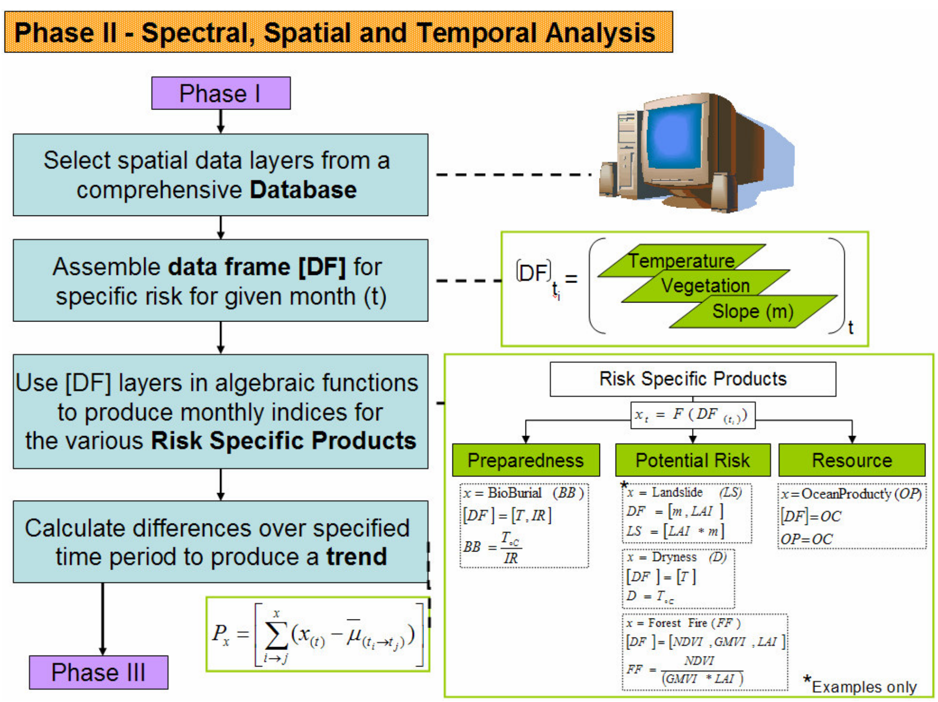
Source: University of Washington

Phase II: Analysis Methods

The SPURS-EM program tested a conceptual integration procedure that evaluated how image data and their derived products could be combined with other static data layers in a GIS to test disaster probability scenarios and affect decision making processes. The SPURS-EM team reevaluated and adapted the conceptual framework several times during the course of the project.

The first step in the analysis process, following the collection and archiving of SRS data, was the collection of spatial data layers to support hazards analysis (Figure 16). When the SPURS-EM project began in 2002, EMD had very little spatial data, most of which included no metadata, and had not undergone a standard QA/QC process. The SPURS-EM project required EMD GIS staff to identify and prioritize the acquisition of spatial datasets, and to archive the data in a manner that would support hazards analysis. EMD GIS staff collected a wide variety of thematic data layers including elevation, hydrology, geopolitical boundaries, infrastructure, and hazard-specific data. The analyst organized spatial data into categories and stored these data as shapefiles, coverages, geodatabases, and rasters in a hierarchical folder structure. EMD continues to use these data for a variety of applications, including spatial analysis, map making, and web services.

Figure 16: Analysis Methods Overview



Source: Univesity of Washington

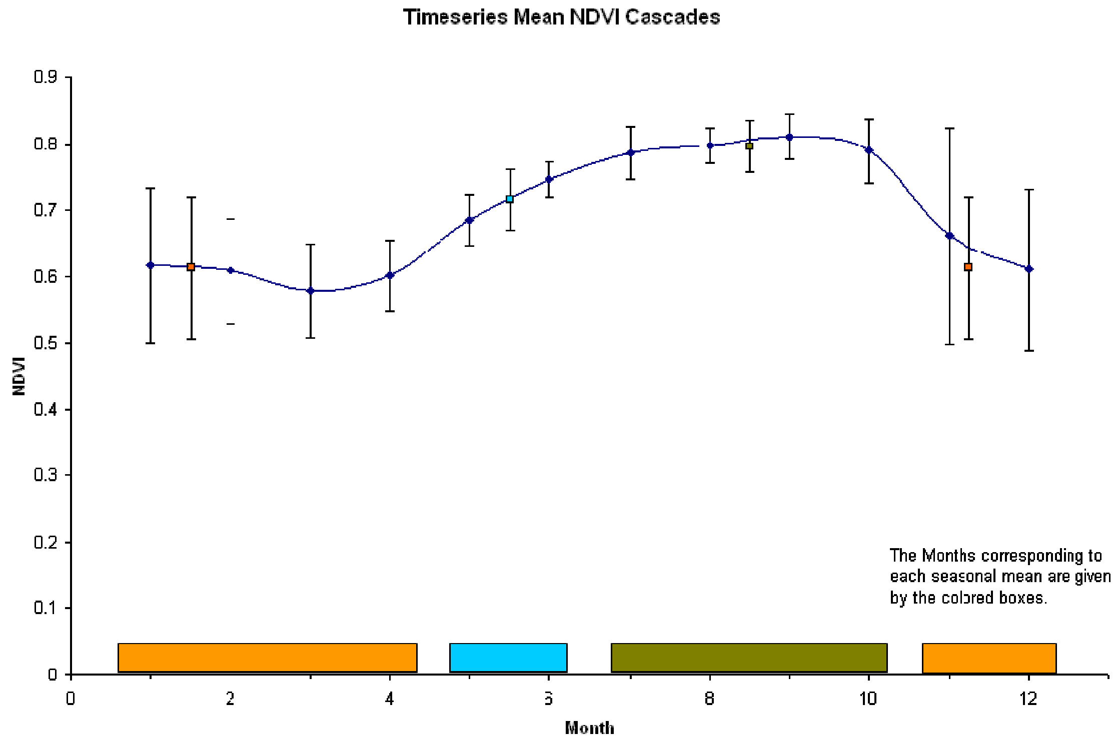
SPURS-EM focused on the analysis of natural hazards, specifically wildland fires and droughts. In the early stages of the project, the SPURS-EM team sought to develop products to serve other predictive functions such as landslide prediction and identification of land areas appropriate for mass bio-burial. *Bio-burial* refers to the need to dispose of large quantities of animal carcasses following a mass animal casualty event. Bio-burial was initially perceived with much skepticism. However, the U.S. has experienced this type of event in the past and the strong agricultural presence in Washington State warranted consideration of this type of event as a plausible threat. Following repeated attempts to develop algorithmic analysis solutions to assess risk in a predictive mode, the team determined that the landslide and bio-burial hazards exceeded the spatial and temporal limitations of the data being used. The development of algorithmic analysis solutions continued for some time with limited success. The Product Team eventually found that the qualitative visual analysis and quantitative statistical analysis yielded better results than the algorithmic approach, and focused their efforts on developing those methods.

The analysis procedures used in this research relied heavily on the use of ArcGIS software and associated applications, which were used in each phase of analysis. The analyst used ArcGIS to construct a powerful analysis environment to support qualitative visual analysis and quantitative statistical analysis. The ArcGIS environment also allowed the analyst to control aspects of the data such as data type, extents, symbology, projections, and cell values. The analyst selected spatial data relevant to the specific hazard being analyzed, added those vector and raster data to the ArcGIS data frame, and organized them into functional groups. For example, spatial data used in wildland fire analysis included slope, transportation infrastructure, historical occurrence of fires, and classified landcover. The analyst used these data to gain insight into the location of historical fires, potential locations for new fires, fire behavior, and accessibility for fire response. These data were complimented by the appropriate SRS datasets for the given hazard/month. Typically, the analyst selected the most current monthly image of Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), and Leaf Area Index (LAI). In the case of wildland fires, MOD14A2 Fire and Thermal Anomalies data provided near-real-time observations. The Product Team found the MOD14A2 product to be useful in many cases, although it was not identified in the original proposal.

ArcGIS supports a wide variety of algebraic functions that enable users to perform complex spatial analysis. The Spatial Analyst extension, which supports the bulk of spatial analysis processes available in ArcGIS, provides a Raster Calculator as a tool for performing map algebra. The analyst performed algebraic functions on a variety of vector and raster datasets. Common vector functions included location queries to identify and illustrate areas that displayed specific attributes. For example, the analyst constructed a query to locate all census blocks within 10 miles of a hazard area, which provided an estimate of populations at-risk to specific hazards. Common raster functions included conditional statements to identify and illustrate areas that exhibited specific values. For example, the analyst created a conditional statement to calculate those cells whose values exceeded the cell values of another raster. The output raster provided a means of detecting change between two raster datasets. This type of function was very useful in detecting areas of significant change.

Quantifying change and considering that change over space and time was the final step in the analysis process. The analyst identified areas of significant change, and compared the level of change to both recent and historical conditions. Analyzing zonal statistics for each ecoregion illustrated a variety of trends that increased our understanding of Washington State and how changes in ecosystem stability relate to hazard occurrence. The team found that the nine ecoregions of Washington State are subject to variable seasonal vegetation and temperature patterns with some ecoregions characterized by four distinct seasons with marked transitions, while others have only two or three seasons (as shown in Figure 17). Although an interesting finding, the presence of variable seasonal patterns had little impact on hazards analysis. Analysts also found that significant departures from historic norms were not uncommon and often did not result in increased risk. For example, in one instance the analyst interpreted the combination of abnormally high LST and abnormally low NDVI as a sign of impending drought as surface temperatures were warmer and vegetation less healthy. The U.S. Drought Monitor, a nationally accepted tool for predicting and monitoring drought conditions nationwide, corroborated the analysts' findings. In this example, the abnormally high temperatures resulted in an early snowmelt that fed streams and aquifers, resulting in a slow return to near-normal vegetative conditions.

Figure 17: Time Series Statistics – Mean NDVI for the Cascades Ecoregion (4)



Source: University of Washington

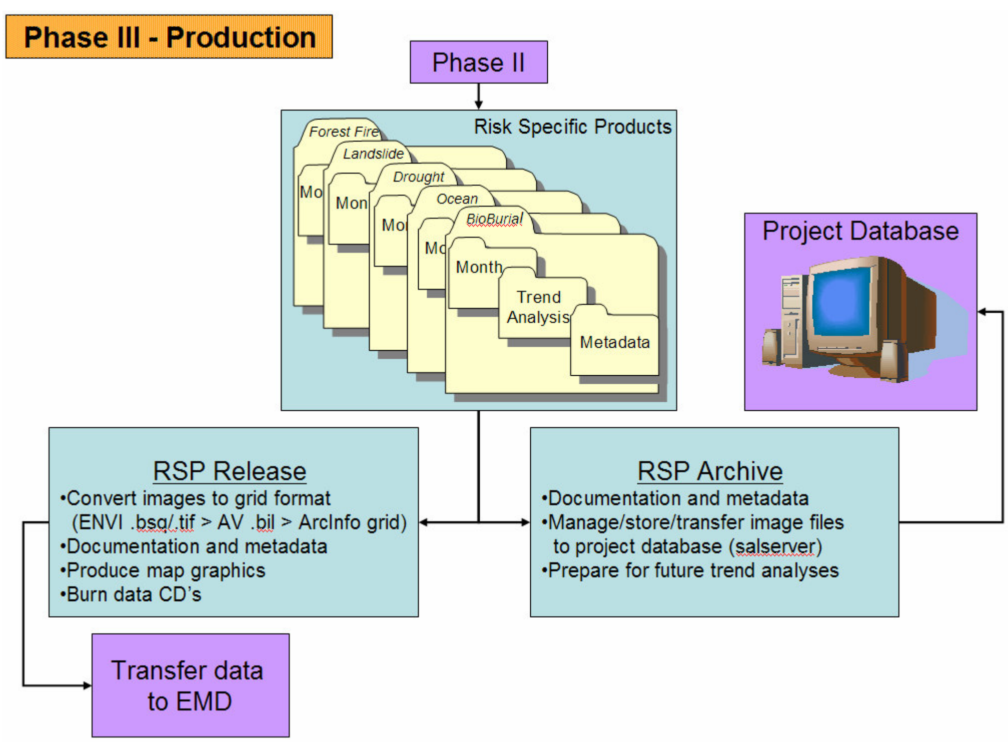
The change detection and analysis process identified some of the more perplexing issues of this research. The team realized that the determination of risk over space and time could not be geographically discrete because conditions in other areas can directly influence conditions elsewhere, a relationship that challenged the modus of our research, which focused on determining risk by ecoregion. The team was also unable to assign a weighting system to assess the significance of observed departures from normal, which limited our ability to conduct a quantitative assessment of the accuracy of risk assessments. The SPURS-EM Team continued to develop and test new approaches to hazards analysis in spite of these challenges.

Phase III: Production

The Production Phase (Figure 18) involved a unique set of activities at both the University of Washington and EMD. The Product Team focused on the development of project deliverables, documentation of research and development activities, and the delivery of data, metadata, and documentation to EMD, while EMD staff focused on the creation of: Monthly Hazard Analysis Reports (MHAR); a procedural manual for data acquisition, processing, and analysis, and; methods of distribution for risk assessment results.

The Product Team developed a variety of products that met or exceeded the expectations set forth in the project proposal. Product documentation was one of the most important products provided by the Product Team. The Product Team developed a final report, which consisted of a compilation of data, images, documentation, and tools organized and conveniently delivered in DVD format. Specific deliverables included documentation of the adaptive landcover classification, the SPURS-EM Metadata Browser application, product documentation and image samples, and reports. Specific details for project deliverables are provided in the *Project Deliverables* section of this report.

Figure 18: Overview of Production Methods



Source: University of Washington

Integrating SRS in Emergency Management

EMD established the Integration Team to coordinate the integration of SPURS-EM products into emergency management. The primary task of the Integration Team was to determine methods to package and deliver data and information to our primary constituents, the local jurisdictions. EMD previously distributed Monthly Hazard Analysis Reports (MHAR) to state and local emergency managers for over four years. The MHAR, a component of the original Strategic Forecast Support System (SFSS), provided current information and analysis results for hazards in Washington State and science-based assessments of the potential for future risks. The Integration Team determined the MHAR to be too subjective in nature and in need of more science-based analysis to ensure quality and confidence in the results. The team concluded that the integration of SPURS-EM analysis results into the MHAR was a logical solution because both the MHAR and SPURS-EM project focused on mitigation and preparedness.

Delivering the results of the SPURS-EM project to the emergency management community was very challenging. Scientists and emergency managers have different needs and priorities and these groups think and operate very differently. The team’s choice to use ecoregions as analysis zones, while useful in the research, complicated the transfer of information from the analyst to the users. Emergency managers generally think and operate based upon geopolitical boundaries. For example, emergency managers are concerned with what fire district is responsible for responding to a fire or what emergency management jurisdiction is responsible for coordinating an evacuation. The team felt that emergency managers did not respond well to the ecoregion-based risk assessments because they were unable to relate to the geographic scope of the assessments. It was difficult for local emergency managers to make decisions based upon boundaries that were different from that of their jurisdictions and to understand how risk was distributed in their region and the regions that surrounded them.

The analyst developed reports that provided detailed risk assessments for each ecoregion and were integrated into the MHAR. Each report included an executive summary that condensed analysis results; individual sections for each ecoregion described various hazards and risk conditions for the previous three months, the current month, and the coming three months, and; ecoregion statistics and other remote sensing indices (e.g. Standardized Precipitation Index, and Palmer Drought Index). Limited feedback from the MHAR readership suggested that, while readers enjoyed the new information (particularly the imagery) they were not sure how to apply it in their jobs.

PROJECT DELIVERABLES

Adaptive Landcover Classification

The primary mission of EMD is to protect the people, property, economy, and environment of Washington State. Effective planning is enhanced with a current inventory of landcover and land use information, and remotely sensed landcover and land use data may be adapted to many applications of emergency management. Emergency Managers can use landcover data to determine the availability of fuels for wildland fires, the presence of croplands that could be at-risk to flooding, or depth of snow that could result in increased avalanche risk. These are just a few examples of how landcover can be used to support emergency management.

The Adaptive Landcover Classification focused on the development of an adaptive, classified general landcover dataset set for use in the SPURS-EM project and general hazards analysis. While a variety of landcover classifications are currently available, factors such as spatial resolution and geographic extent limited the applicability of these datasets in the context of SPURS-EM. While some datasets offered higher resolution, they lacked the geographic extent necessary to conduct statewide analysis. Other landcover datasets provided statewide coverage but were not current. The development of an adaptive landcover classification was a challenging aspect of this project that and was never fully developed for a variety of reasons, which are discussed in this section.

The SPURS-EM Product Team began developing the Adaptive Landcover Classification by reviewing the role of landcover in current and future applications. The team determined that the ability to adapt a general landcover dataset to support the analysis of different hazards was a high priority. However, the team eventually realized that it was less important that general landcover be adaptive to specific hazards, but rather to regions. The Product Team identified various landcover products that could be used in certain regions of the state, which are listed in Figure 19.

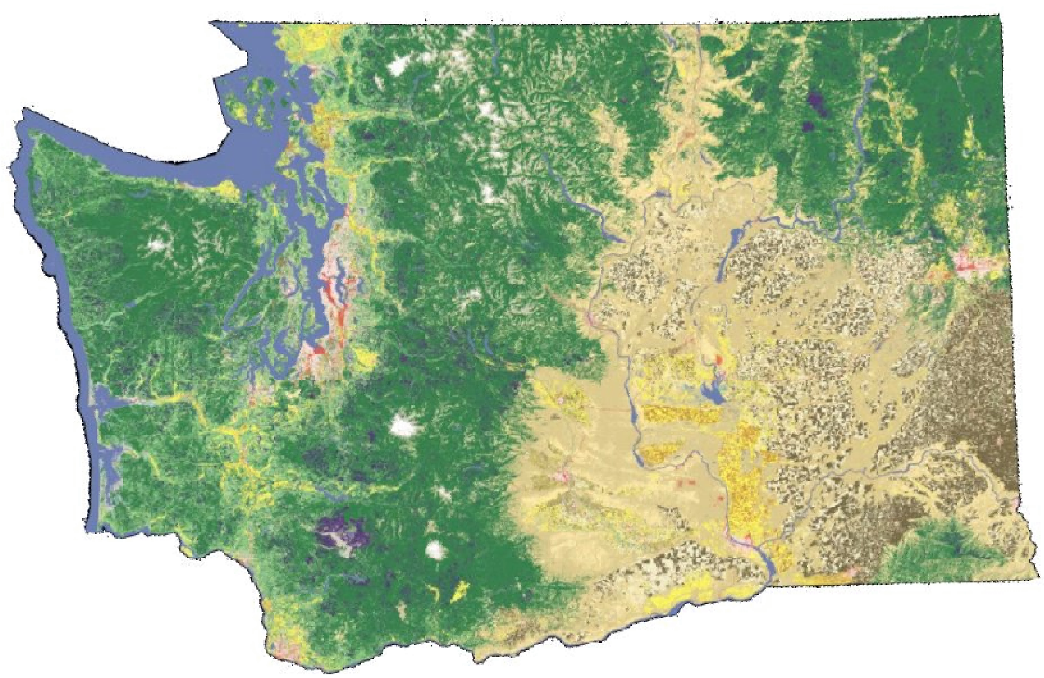
Figure 19: Landcover Datasets

TITLE	SOURCE	GEOGRAPHIC EXTENT	RESOLUTION	LAST UPDATED
National Landcover Dataset (NLCD)	USGS	Statewide	1-kilometer	1992
MOD12Q1 96-day Landcover	NASA	Statewide	1-kilometer	2002
Puget Sound Landsat Landcover	PRISM	Puget Lowland	30-meter	2001

Source: University of Washington, Washington EMD

In the Puget Sound region, data products derived by the Puget Sound Regional Synthesis Modeling program (PRISM) provided high-resolution data and a uniform classification system for the urbanized regions of western Washington. The USGS National Landcover Dataset (NLCD) offered consistent data for statewide issues or hazard events (Figure 20). The team intended to use NASA MODIS 96-day Landcover dataset (MOD12Q1) to address hazard issues that required more timely information. The Product Team determined that the datasets listed above best met the needs of the SPURS-EM project, although other landcover datasets were available (e.g. ASTER landcover and the Global Landcover Classification (GLCC)).

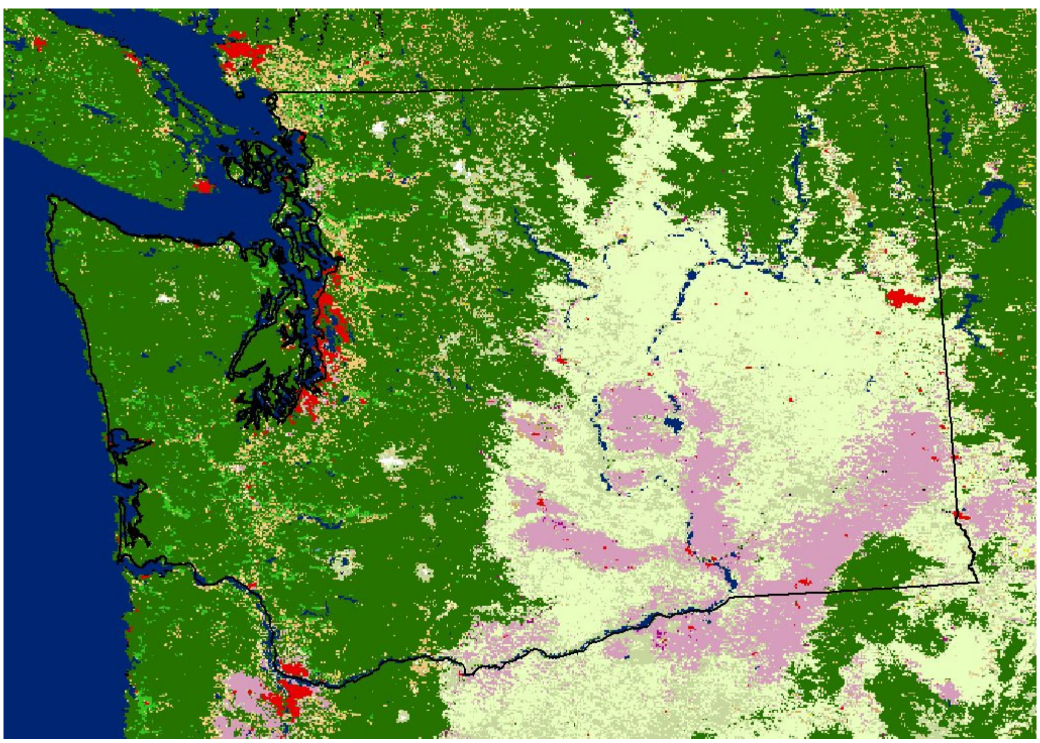
Figure 20: USGS National Landcover Data (1992)



Source: United States Geological Survey (USGS)

The team encountered a variety of difficulties in the development of the adaptive landcover classification, the most important of which was the availability of data. Both the USGS National Landcover dataset (NLCD) and the NASA MODIS Landcover dataset (MOD12Q1 – Figure 21) were not updated on schedule, which severely inhibited our use of these datasets. The most recent NLCD dataset was produced in 1992 and an updated version of the Washington State data was scheduled for release in 2002. This dataset is still unavailable as of the date of this report. The MODIS dataset is supposed to be updated every 96 days, but has met with delays and has not been updated since June 2003. The SPURS-EM Team relied heavily upon the MODIS dataset to enable the adaptation of our landcover dataset to reflect current conditions. The SPURS-EM Team intended to integrate the NLCD and MODIS landcover datasets into a single, adaptive landcover classification, but could not because of the aforementioned challenges. EMD staff continues to pursue the development of an adaptive landcover classification and will complete this deliverable when data is available.

Figure 21: MODIS MOD12Q1 96-day Landcover Product



Source: University of Washington (2004)

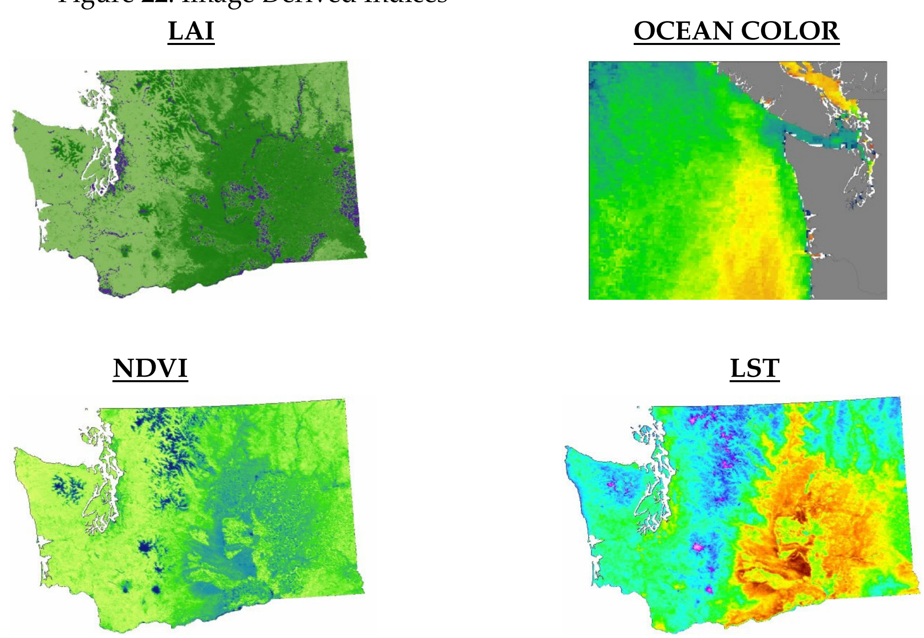
Image-derived Indices

EMD staff developed procedures for generating monthly indices characterizing biophysical conditions that affect ecosystem stability, and provided the image-derived indices tested during the evaluation and testing phase of the SPURS-EM project. The Product Team initially suggested five indices that may be useful in emergency management. These indices, shown in Figure 22, were:

- Normalized Difference Vegetation Index
- Land Surface Temperature
- Leaf Area Index
- Ocean Color
- Spectral Mixture Analysis (not shown)

The SPURS-EM project used the Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) indices extensively. NDVI represents the spectral vegetation index of greenness or plant vigor, and was used to examine vegetative health in individual ecoregions. The team chose to use NDVI because vegetation is an influencing factor in many of Washington's major hazards, including wildland fires, floods and drought. The team also used LST in many applications due to its relevance to the wildland fire and drought hazards. NDVI and LST were the most useful indices in hazard analysis and in the development of the AVHRR/MODIS time series.

Figure 22: Image Derived Indices



Source: University of Washington and Washington EMD

Leaf Area Index (LAI) was also used throughout the SPURS-EM project. LAI represents the spectral vegetation index of plant biomass. LAI provided a subtle difference in meaning and use, but was used less extensively than NDVI and LST. During testing, the application of LAI fell mostly into a "conformation" or "validation" of the EMD staff's interpretation of the vegetation landcover data and the NDVI time series.

The Product Team concluded that the Spectral Mixture Analysis products, specifically non-photosynthetic vegetative indices, were not meaningful tools after reviewing both the processing requirements and the utility of the indices to provide additional information to the EMD staff. Spectral Mixture Analysis was a fundamentally different approach to processing the spectral data per pixel in remotely sensed data images. By seeking to derive the percentage of a "mixed" spectral signature from a library of "pure" signature specifications, the result is an estimate of a pixel composition for each library spectra. In practice, this required the development of a library of spectra, which may be used on a monthly basis, or a procedure for the development of a spectral library for each monthly image. In consultation with the EMD staff, the scope of this work was determined to be unsuitable for an applied setting and our efforts were directed elsewhere.

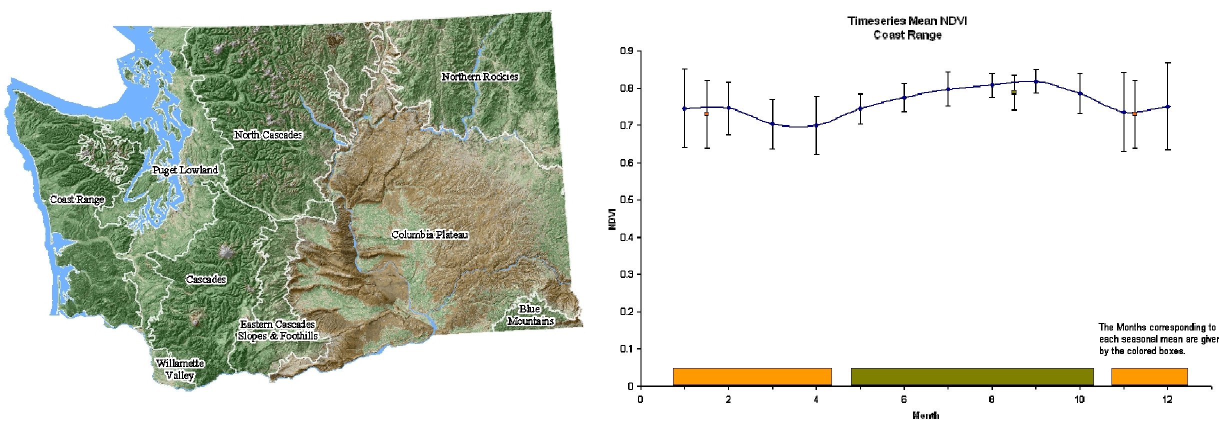
The Product Team collected Ocean Color (Chlorophyll) for the life of MODIS, but did not test its application in emergency management. The Product team planned to test the use of Ocean Color data for a variety of marine hazards including oil spills and harmful algal blooms. While the data was determined to be capable of identifying these events, its application in the mitigation and preparedness phases was not assessed.

Time Series & Ecoregion Statistics

When the project was first envisioned, the team was unsure what role historical trends would play in hazard analysis. The team found historical data were critical in hazard analysis and became the foundation for the monthly hazard analysis processes (UW Team Final Report). Historical data was considered a high priority in helping emergency managers prepare for mitigations and planning activities.

The Product Team acquired 20 years of bi-monthly and monthly mean AVHRR reflectance data, and derived NDVI, and LST data for the entire State of Washington. The team addressed all of the geo-registration issues, instrument calibration requirements, and provided metadata and database documentation. The time series datasets consist of historical imagery from 1981 through 2004 collected by the Advanced Very High Resolution Radiometer (AVHRR) instrument and imagery collected by MODIS from 2000 through present. Each time series was visualized as an image and statistically (Figure 23).

Figure 23: Time Series Visualizations (Images and Statistics)



Source: University of Washington and Washington EMD

The two data sets developed to assist in hazard risk assessment are uniquely processed for each EPA ecoregion of Washington State. The analysis of these data focused upon both the variability of the indices within the eco-regions of the state of the annual cycle, and variability of the indices within the eco-regions over the whole of the time series. In this way, each ecoregion was assigned "threshold" values for both NDVI and LST for each month, which describes anticipated variability based upon the past 20 years of data. Variation from these "threshold" values suggested regions of concern in the monthly analysis procedure.

Metadata and Image Browser

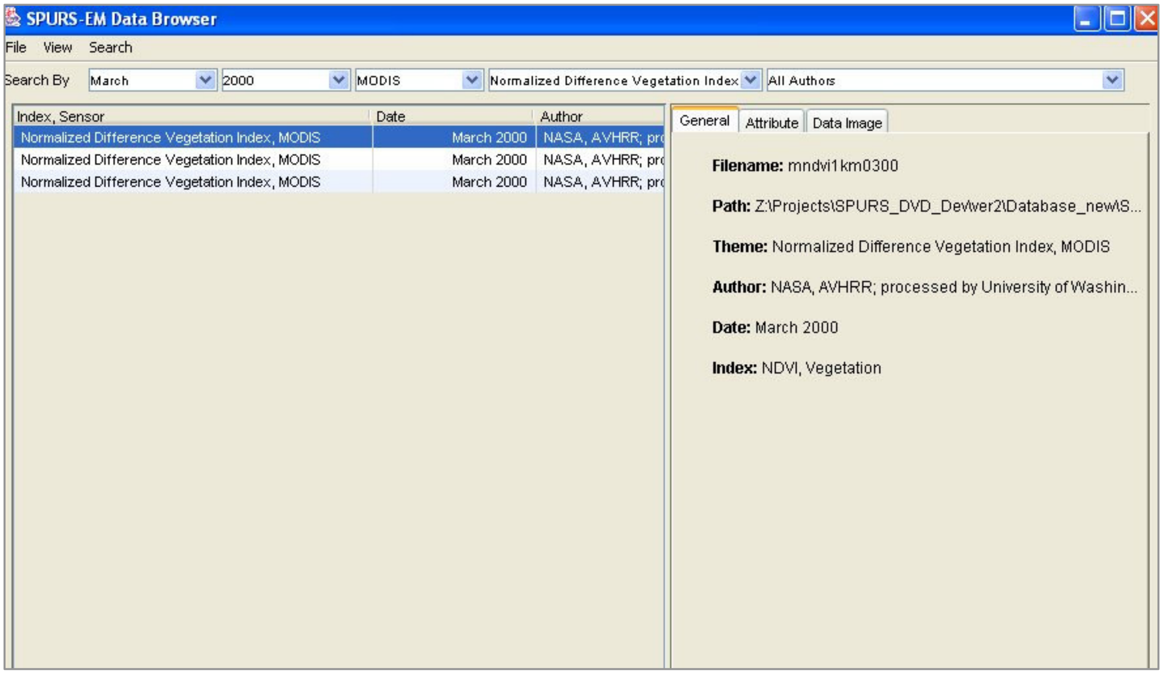
SPURS-EM focused on the planning and mitigation phases of emergency management. The primary task in these phases is the identification of required data for analysis. The Product Team developed a searchable database and interface to query and access SRS data to streamline the process if identifying data to be used in hazard analysis. The SPURS-EM Metadata Browser consists of a database designed to provide a rapid query of all available remotely sensed products archived by EMD.

Metadata is essentially "data about data", and generally consists of descriptive information (e.g. Title, Abstract, and Spatial Resolution) about digital geospatial datasets. In the SPURS-EM Metadata Browser, all remotely sensed products and the original multispectral data include ancillary information regarding their lineage and processing. A database of this information and the data products themselves constitute the SPURS-EM database.

The Product Team inventoried all metadata for all data products using an extendable markup data language (XML). This markup language allowed for the development of a desktop query tool, which we refer to as a desktop product search engine. This product search engine explores the data collection on a local hard drive or network based on a users' request for an inventory of data products that conform to a selection criteria of the image index type, image date or image sensor type.

The Product Team developed a search tool in order to provide an interface to the metadata database (Figure 24). This application was written in the Java programming language and runs on all Windows-based platforms. Because the data that is queried by this tool is provided in XML, the application requires very little memory and is appropriate to be installed on all EMD desktops. The SPURS-EM Metadata Browser lists all SRS data products by type, author, resolution, etc, and provides an array of search options that are both logical and user-friendly. The tool also provides a summary of metadata for each selected dataset that provides a quick overview of the image being queried (Figure 24). If available, a thumbnail image will also appear that displays a symbolized version of the image.

Figure 24: SPURS-EM Metadata Browser



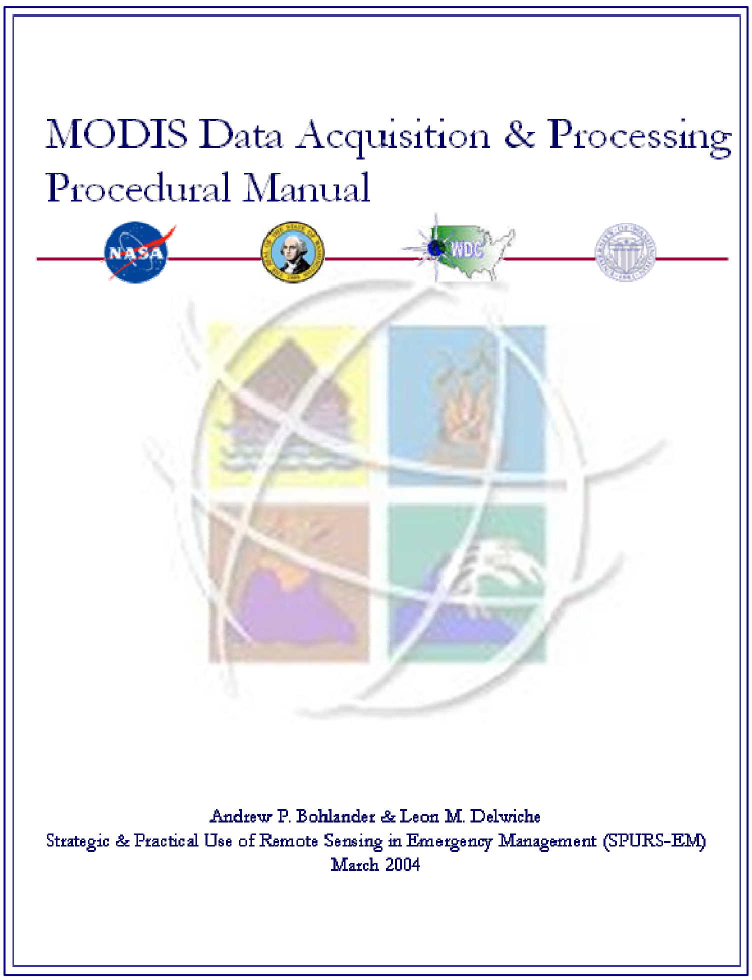
Source: University of Washington (2004)

The SPURS-EM Metadata Browser provides EMD analysts with a convenient tool to use internally, but also an opportunity to share data with external partners in the public and private sectors, and academia. EMD stores all available SRS data on both a protected network and a shared portable hard drive that can be used to upload data to user machines outside of EMD. The SPURS-EM Metadata Browser is provided as a distributed application, and offers external users the same capabilities as EMD users. The SPURS-EM Metadata Browser can also be used to query other forms of geospatial data such as shapefiles, coverages, and geodatabases. EMD currently utilizes the ArcCatalog application, which is part of the ArcGIS product suite, to preview, search, and process geospatial datasets. However, the ArcCatalog application does not provide a search function, often making it difficult to locate data. The SPURS-EM Metadata Browser provides EMD with a new query and search capability that supports both the SPURS-EM project and the EMD GIS Program. This application is available upon request for unrestricted public use.

Data Processing Procedural Manual

EMD was initially concerned with their long-term ability to retain the knowledge, skills and abilities needed to make use of SRS data in hazard analysis. The need to retain skills became evident in the early stages of the project as EMD realized the technical and time-sensitive nature of the data acquisition and processing phase. The hazard analyst adhered to a strict schedule of ordering, downloading, processing, and analyzing SRS data in order to provide monthly products on time. EMD realized that in order for the project to be successful, it was essential to gain sufficient knowledge and the skills needed to ensure that project functions could be completed in the absence of the hazard analyst. To accomplish this objective EMD began documenting the activities of the Product Team and hazard analyst, and the procedures used to develop products and perform hazards analysis, was a critical task.

Figure 25: MODIS Data Acquisition & Processing Procedural Manual



Source: University of Washington and Washington EMD

The hazard analyst developed the MODIS Data Acquisition & Processing Procedural Manual (Figure 25) to facilitate the transfer of knowledge and provide documentation of project activities and methods. The manual provides EMD staff with a desktop reference and instructional guidebook for ordering, downloading, processing and archiving SRS data products each month. The manual documents the entire process of data acquisition, beginning with the establishment of a user account with the EOS Data Gateway and provides "click-by-click" procedures with screenshots and descriptions of specific actions as well as web links to helpful resources such as the MODIS Reprojection Tool download page, and the EOS Data Gateway homepage. The manual also includes descriptions of all MODIS data products used in the SPURS-EM project. The manual provides not only a means for EMD to retain the knowledge gained through the SPURS-EM project, it also can be used as a training tool for future data users and is available upon request for unrestricted public use.

PROJECT RESULTS: OUTPUTS, OUTCOMES & IMPACTS

Outputs

Education, Training & Outreach

The Integration Team coordinated both internal and external outreach and education efforts. The team developed a series of education and training opportunities in a variety of formats ranging from formal coursework in a university setting to small group sessions focusing on individual remotely sensed indices. Members from both UW and EMD delivered public presentations local, regional, national and international conferences. Venues included Honolulu, Hawaii, where the project received an Innovations Award from the Council of State Government (CSG) West. The project Principal Investigator also spoke at the GIS in Telecoms Conference in Nice, France and a conference of the National Academy of Sciences in Washington D.C., both in 2002. A variety of media supported education and outreach efforts including a SPURS-EM project tri-fold brochure, a standup display booth for use at conferences, and a variety of posters that appeared at various workshops, conferences and other venues.

The Product Team provided geospatial training and educational opportunities to EMD staff during the initial stages of the project and training remains an ongoing activity. EMD staff provides internal training opportunities both formally in the form of classes, and informally through daily interaction. The increased presence of geospatial technology in the form of maps, presentations, and meetings has had a profound impact on the agency and has changed perceptions of technology. GIS and Remote Sensing were not household terms at EMD prior to the SPURS-EM project, due in part to the fact that EMD was limited to only one part-time GIS staff, and the acceptance of GIS as a critical function of emergency management was very limited at the time.

The SPURS-EM Project presented a unique opportunity for members of the academic community to learn about the emergency management discipline and to consider how their knowledge as scientists is applied in the phases of mitigation, preparedness, response and recovery. UW staff participated in exercises at the State Emergency Operations Center (EOC) where they were exposed to the range of activities coordinated during the emergency response phase. UW staff recommended that a geospatial expert be present in the Policy Room to support the decision-making process during emergencies and disasters.

The primary reason for this recommendation was to ensure that decisions were made based upon accurate interpretations of the best available science.

The transfer of knowledge from UW and the remote sensing community at large was an excellent learning experience for many EMD staff. Prior to the SPURS-EM project, knowledge of geospatial technologies, particularly remote sensing, was nearly nonexistent at EMD. EMD staff acquired remote sensing education through graduate level remote sensing coursework at the University of Washington and exposure to new remote sensing software packages such as ENVI and IDRISI. The Product Team also provided a series of training sessions that focused on both the conceptual and applied aspects of GIS and multi-spectral remotely sensing.

Data Collection

The team collected SRS data and other forms of geospatial data to support a variety of project activities including the selection of datasets for time series development and hazards analysis, vector data to support hazards analysis, and other datasets to be tested for effectiveness in mitigation, preparedness, response and recovery. The data collection process initially focused on the collection of relevant SRS image data to support the development of an adaptive classified landcover dataset, and monthly indices that characterized aspects of the biophysical condition of Washington State. Metadata was assembled for these data, assessed for quality where possible, and archived.

The team collected the following indices for the entire 5-year MODIS life span:

- Surface Reflectance
- Land Surface Temperature
- Normalized Difference Vegetation Index
- Leaf Area Index
- Ocean Color

The team collected the following indices for AVHRR over 20 years:

- Normalized Difference Vegetation Index
- Land Surface Temperature

The team collected the following landcover datasets to support the development of an adaptive landcover classification:

- USGS National Landcover Characterization (NLCD) 1992
- MODIS MOD12 Landcover and Landcover Dynamics

- PRISM General Landcover of Puget Sound

At the time of this publication, the SPURS-EM team had acquired and processed over 1400 raw AVHRR images of NDVI and LST, and almost 1000 MODIS images including NDVI, LST, LAI, and Ocean Color. The team created metadata for each dataset using the extensible markup language (XML), and all datasets (raster and vector) are available from EMD at no cost. The SPURS-EM team recognizes the value of the historical NDVI and LST time series as a contribution to the science community.

Data Development

The acquisition of SRS data was the first step in converting SRS image data into image-derived products for use in hazards analysis. The data development process refers to the activities that took place following the collection of raw data, and focused on processing, and archiving SRS image data for the SPURS-EM project. The data development process was essentially the same for AVHRR and MODIS datasets, with some slight variations to accommodate differences due to instrument calibration and native file format.

The data development process consisted of the following seven steps: order, download, project, mosaic, convert, export, and archive. MODIS data processing required over 3 months of work to complete. Heavy bandwidth requirements during the download process made MODIS data difficult to work with and often required the hazard analyst to download data products after business hours and on weekends. MODIS data came in the Hierarchical Data Format (HDF) – the native format of NASA EOS data products – which made it difficult to work with the data in standard commercial-off-the-shelf applications (COTS) and required an additional investment in software and training. AVHRR data processing was also very work-intensive. Development of the 20-year AVHRR time series and integration of that time series with the 5-year history of MODIS required a linear regression analysis, which took considerable time and effort to develop. Data development for both AVHRR and MODIS required significant time and effort and limited the amount of time the team had to develop analysis methodologies. Each image also required significant memory for storage, which increased the archiving costs. Storage requirements were difficult to accommodate initially and required the purchase of a dedicated server and additional memory for local user machines. This was not recognized as a significant limitation in utilizing NASA data products, as it is a common problem with most geospatial data.

Data development also involved the creation of new data, which was typically derived from existing datasets. One of the data development goals of the SPURS-EM project was the development of an adaptive landcover classification that would provide continuous coverage of Washington State and be adapted to reflect current conditions as they change over time. EMD staff conducted a critical assessment of available datasets to support the development of an adaptive landcover classification. The team reviewed each dataset based upon spatial resolution, geographic extent, classification methodology, update availability, and ease-of-use. The goal of developing this dataset was never achieved due to a lack of available data. The new landcover classification required input from several sources and it was critical that those sources reflected current conditions. The team found that most landcover datasets were not released on schedule and that available statewide datasets did not meet accuracy and/or resolution requirements set forth by the team. The data development strategy relied heavily upon the unavailability of MODIS MOD12Q1 96-day Landcover data, which is supposed to be updated every 96 days and has not been updated since June 2003.

One of the project goals that was not identified in the original proposal, and was realized during the initial planning phase, was the intent to extend the scope of the project beyond the terrestrial boundaries of Washington State and address one of our state's most valuable resources, the ocean. To accomplish this goal, the team collected a 5-year history of MODIS Ocean Color (Chlorophyll) data. The team intended to use these data to identify areas where risk would be elevated if a damaging event, such as an oil spill or harmful algal bloom, should occur in the marine waters adjacent to Washington State. Chlorophyll is generally a sign of increased photosynthetic activity and can be used to monitor the health of marine waters. The team examined the application of MODIS Ocean Color data in the mitigation and preparedness phases by identifying concentrations of marine organisms and considering that, if a damaging event were to occur in those areas, ecosystem losses would be more significant. This information was also intended for use in the response phase to quantify expected losses. At the time of this publication, the use of MODIS Ocean Color data in emergency management remains largely unknown.

The team used monthly NDVI and LST grids to derive Level III Ecoregion statistics, one of the primary outputs of the SPURS-EM project. The analysts exported Level III Ecoregion statistics to MS Excel and analyzed behavioral changes and trends in NDVI and LST in each ecoregion. The team primarily considered departure from the mean in terms of standard deviations. Ecoregions that exhibited significantly "abnormal" values for a given month would undergo additional analysis to determine the potential cause of the abnormal behavior. In many instances, significant departures from normal did not create hazardous conditions. However, in some cases, these changes were associated with hazard events. For example, significantly below-normal values of NDVI during the month of July 2003 indicated the potential for increased dryness of vegetation. The analyst used this information, coupled with the knowledge of vegetation type (determined through landcover data), and slope (derived from a digital elevation model) to determine an increased potential for wildland fires. Additional analysis revealed that low NDVI values were likely the result of previous fires in the region that left vegetation completely burned, resulting in very low values of NDVI. The team considers the ecoregion statistics to be a valuable contribution to the science community.

<u>Outcomes</u>

<u>Increased Use of GIS and RS</u>

The most obvious change due to the SPURS-EM project is the marked increase in awareness and demand for geospatial products at EMD. Event mapping in the Emergency Operations Center (EOC), hazard analysis, and general mapping and modeling have changed many people's perceptions and attitudes toward geospatial technologies. GIS is increasingly being recognized as a critical business function and requests for EMD geospatial products are at an all-time high. The acceptance of, and demand for, SRS products has not kept pace with the increased demand for GIS-based products. The team attributes this to the complex nature of SRS and the fact that general raster and vector data are more commonly used in the emergency management community. For example, while the use of Hyperion hyperspectral data in an urban analysis environment would be highly desirable, it is not necessary to meet the information needs of the average emergency manager. Emergency managers generally require an understanding of an event's location, geographic scope, and severity in terms of impacts to people, property, economies, and the environment. While SRS can be very useful in assessing impacts to the environment, more standard geospatial datasets (e.g. census and infrastructure data) often provide sufficient accuracy. Despite the tendency for emergency managers to demand GIS products opposed to SRS products, EMD staff continues to utilize SRS data in the hazards analysis process and consider these data valuable to emergency management.

The SPURS-EM project also enabled the purchase and upgrading of hardware, software and data, which has improved workstation performance, enhanced software capabilities, improved access to more accurate data, and resulted in significant improvement to the EMD GIS Program and its ability to provide geospatial services to both internal and external clients. These new and enhanced capabilities have enabled EMD GIS staff to improve their skills and develop stronger partnerships with other GIS and Remote Sensing professionals in the Pacific Northwest. As a result, the perception of GIS and Remote Sensing within EMD is changing from one of cautious acceptance to genuine support. EMD management has committed to the long-term support of geospatial activities, and expects remote sensing remain a part of the EMD GIS Program. GIS and Remote Sensing have also gained acceptance within the Military Department, the agency within which EMD is located. The Military Department Information Services Division (ISD), which coordinates all Information Technology (IT) resources for the Department, is actively integrating geospatial activities as key business functions in the Department's IT Strategic Plan.

Developed New Products

The SPURS-EM project designed products to enhance the use of science and technology in the emergency management decision-making process. Although SPURS-EM focused on the phases of mitigation and preparedness, emergency response was considered, as it is a critical function of emergency management where remote sensing has value. The team succeeded in deploying geospatial technologies during emergency operations and enhanced event mapping and analysis capabilities during emergency activations and exercises. The EMD GIS Program is now receiving additional funding through internal and other programs such as CSEPP (Chemical Stockpile Emergency Preparedness Program), which has provided funding and resources to develop and implement a web-based event mapping system in the Emergency Operations Center (EOC). The support of the CSEPP program is indicative of the paradigm shift in support for geospatial technology at EMD.

The SPURS-EM project also enhanced the Monthly Hazard Analysis Report (MHAR), which was part of the original EMD Strategic Forecast Support System (SFSS). SPURS-EM analysis results enhanced the scientific basis and credibility of the MHAR, thereby providing a more accurate and reliable product to the readership, which consists largely of local emergency managers. The SPURS-EM Metadata Browser provides EMD with a value-added product that supports both the project and the EMD GIS Program. Source code for the data browser can be adapted to meet the needs of the program, making it a versatile tool. The AVHRR/MODIS NDVI and LST time series and ecoregion statistics are products that can be used for various studies outside of EMD. These products are scientifically valid and offer value to the scientific and emergency management communities. Education and outreach products that were developed through this project have also added value in that EMD staff are now better informed and more capable of leveraging the power of geospatial technologies. EMD outreach activities have also increased our visibility in the local and regional GIS communities, which has led to new colleagues and new opportunities.

Impacts

The SPURS-EM project introduced EMD to many new agencies and individuals who utilize GIS and Remote Sensing in their various professions. Since the beginning of the project, EMD staff has worked with GIS professionals in many fields including natural resources, health, infrastructure, agriculture, ecology, transportation, and law enforcement. These new relationships create opportunities to share ideas, provide support, share lessons learned and best practices, and develop new projects. The SPURS-EM project supported EMD staff in the following projects:

- Volcanic ashfall modeling with the United States Geological Survey (USGS)
- Volcano hazard mapping with the Washington State Department of Natural Resources (WADNR)
- Emergency response mapping with the Federal Emergency Management Agency (FEMA)
- Development of web services using ArcIMS for the Washington State Critical Infrastructure Program
- Event mapping for the Chemical Stockpile Environmental Preparedness Program (CSEPP)

One of the most obvious impacts of the SPURS-EM project has been the dramatic increase in demand for GIS and Remote Sensing data products within EMD. EMD consists of four units, each with their own sections, programs, and projects. GIS is one of the few business functions with the ability to support practically every program within EMD. Prior to the SPURS-EM project, when GIS and/or remote sensing products/services were required, they were contracted out through other federal/state agencies, vendors, or consultants. The SPURS-EM project helped EMD to develop the capability to support the mapping and analysis needs of its personnel. An added benefit has been the visibility our geospatial products have enjoyed. EMD GIS staff have published maps and posters at local and regional GIS and remote sensing conferences and workshops, and are frequently recognized by internal staff. EMD GIS products are displayed throughout the agency and in the Emergency Operations Center (EOC). EMD staff now expects high quality geospatial products/services and the number of map requests is constantly rising. The acceptance of GIS would not have been possible without the support of the SPURS-EM project.

Non-Technical Changes

In addition to the development of new products and increased demand for geospatial services, the SPURS-EM project resulted in a number of policy changes at the State level. EMD established procedures for mapping and analysis in the State Emergency Operations Center (EOC) where, prior to the SPURS-EM project, event mapping was practically non-existent and the majority of decisions were made using wall maps and outdated map books. The use of GIS and digital mapping and analysis products during emergency operations has increased dramatically since SPURS-EM began. EMD GIS staff is now expected not only to produce standard event maps, but also to satisfy custom map requests to support emergency response functions such as evacuation planning, traffic control, agricultural embargos, and impact assessments. GIS is also used to develop map products to support EOC briefings, and decision-making in the Policy Room. During every emergency activation and exercise, maps are projected on a large screen in the EOC so that response personnel have an accurate and reliable visual display of the event. EMD GIS staff also coordinates the acquisition and analysis of new scientific data in the EOC. For example, plume data generated through programs such as NARAC and D2-Puff are imported into ArcGIS for subsequent analysis to support volcano hazard response. The SPURS-EM project resulted in an overwhelming acceptance of geospatial technology and increased demand for GIS and Remote Sensing.

Additional policy influence from SPURS-EM is visible in the formation of the Washington Military Department Geographic Information Technology (GIT) Working Group, which consists of IT staff from the Military Department ISD, and GIS staff from EMD and the Capital Management Division (CMD), another division of the Military Department active in GIS. The GIT Working Group coordinates the integration of geospatial technologies into the IT infrastructure of the Washington Military Department. The GIT Working Group developed a set of GIS-specific goals and objectives that are stated in the Military Department IT Strategic Plan, representing a significant policy change within both EMD and our parent agency, the Washington Military Department.

Project Highlights

Since the SPURS-EM project began in 2002, there have been significant accomplishments many of which are difficult to quantify, such as the changed perception of GIS among emergency managers. The acceptance of GIS, and increased demand for geospatial products are significant highlights of the SPURS-EM project. Without the support of NASA, our program would be less capable and event mapping in the EOC would still consist of wall maps and whiteboards. Of the many accomplishments made during the course of the SPURS-EM project, the four that stand out are:

- Geospatial Support for Emergency Operations
- Enhancement of the Science & Technology Program
- Establishment of GIS as a Key Business Function of EMD
- Changing the Perception of GIS in Emergency Management

The establishment of new procedures for event mapping in the State EOC will have a long-lasting positive impact on emergency response activities at EMD. Decision-makers have access to more accurate and reliable information, and EMD staff is more skilled in interpreting and delivering information in meaningful ways. SPURS-EM helped EMD move from outdated hard-copy maps to a new level of sophistication that includes multiple tools and services for mapping and analysis. Aerial imagery has been widely accepted as an excellent form of support for event mapping, and is currently being integrated into other business functions at EMD, most notably the Chemical Stockpile Emergency Preparedness Program (CSEPP) and the Critical Infrastructure Protection Program (CIP). The eruption of Mount St. Helens in October 2004 provided an excellent opportunity to showcase new skills and abilities, as well as to demonstrate new partnerships by working with the USGS, FEMA and WADNR to develop geospatial products to support both response and preparedness.

The establishment of the EMD Science & Technology Program is also a direct result of the SPURS-EM project. The Science & Technology Program focuses on maximizing the benefit of science and technology by integrating geospatial data, interpreting scientific data and analysis results, and offering geospatial services to internal and external customers. The experience gained through SPURS-EM has led to improvements in staff skill and expertise, as well as program resources such as data, hardware, software, and training. The actual benefit of the Science & Technology Program cannot be quantified but can be inferred through the observed changes in agency and personnel perceptions of GIS and Remote Sensing.

In addition to the many aforementioned accomplishments, the successes of the SPURS-EM project were recognized at the national level on multiple occasions. In 2002, EMD staff attended a conference in Honolulu, HI that was hosted by the Council of State Governments (CSG) West. The CSG recognized SPURS-EM as an innovative and proactive solution for state government and invited EMD to share our experience with other project leaders from around the Pacific Rim. EMD received an award as "Runner Up for the Annual CSG West Innovations". In 2003, Rich Davies of the Western Disaster Center submitted an article to GeoSpatial Solutions Magazine describing the SPURS-EM project. GeoSpatial Solutions responded by recognizing the SPURS-EM project as one of the "Best Innovations of 2003". SPURS-EM was featured in the August 2003 edition of GeoSpatial Solutions magazine. SPURS-EM received international recognition by the National Academy of Sciences, which invited the SPURS-EM Principal Investigator to present the project to an international audience at the 2003 Conference of the National Academy of Sciences in Nice, France.

LESSONS LEARNED

To fully appreciate the SPURS-EM project and how remote sensing will be incorporated in the future operations of EMD it is important to understand the capabilities resident at EMD at the beginning of the project as well as the mission of EMD. The mission of EMD is: "To minimize the impacts of emergencies and disasters on the people, property, environment, and the economy of Washington State." EMD addresses all phases of emergency management, which include mitigation, planning, response and recovery. EMD provides the essential role of coordinating overall state activities and local jurisdiction response to emergencies and disasters. EMD is the primary source of actionable information for Washington State's elected leadership during disasters and emergencies, although it is important to emphasize that EMD and other similar state agencies do not function as front-line first responders.

A goal of the SPURS-EM project was to develop a process to integrate continuous use of an adaptive classified land cover product into an EMD monthly hazard specific risk assessments. This aspect of the SPURS-EM project focused on the mitigation and planning mission of disaster management. The goal was to develop a process where EMD could learn from the past and using current earth observations to look ahead to reduce the impact of future disaster events. SPURS-EM was also intended to provide more current remotely sensed information to support the overall hazards analyses and predictive functions of EMD in developing the strategic forecast support system.

The trials and tribulations associated with the development of the SPURS-EM adaptive landcover classification system have been discussed previously in this report. During the SPURS-EM project the monthly hazard specific risk assessments morphed into monthly ecoregion assessments. The monthly assessments addressed ecosystem stability and environment conditions as they pertain to a limited number of natural hazards in the state. After several iterations it was concluded that the ecoregion assessment reports were too generalized for the EMD emergency management community and that they provided limited actionable information for effective disaster mitigation and planning. Further, these reports were not timely enough and not of sufficient detail to be of use during the response and recovery phases in a disaster event. In general, the ecoregion assessments were not well received within EMD and by the Washington emergency management community.

The "state of remote sensing technology" at EMD when the SPURS-EM project began was defined through a series of informal interviews with EMD staff and management. In 2001, EMD was just beginning to integrate Geographic

Information Systems, GIS, into day-to-day operations. The use of HAZUS[1] after the February 28, 2001 Nisqually Earthquake had convinced EMD management of the potential of geospatial technologies and was one of the motivating factors for EMD to pursue the SPURS-EM applied research project with NASA's Earth Science Applications Directorate.

EMD's corporate GIS expertise at the beginning of the SPURS-EM program would be considered minimal. HAZUS is designed to function within ArcMap, an ESRI GIS software product, and requires minimal user training or sophistication to operate. Following the Nisqually Earthquake, EMD used HAZUS in what is called Level 1 Analysis, which relies on default infrastructure and geological data. Today EMD's GIS capabilities have improved vastly and EMD has the capability to operate HAZUS as a Level 2 or Level 3 user, which enables the user to incorporate user-defined information and data. The expertise developed as a result of the SPURS-EM project was, in part, responsible for this improved capability.

At the start of the SPURS-EM project the understanding and comprehension of remote sensing technology at EMD was even less advanced than their GIS capabilities. The results of the informal interview series have been summarized into two questions:

- Does your group use remote sensing today?
- Do you think remote sensing has the potential to support the EMD mission?

About 75% of those interviewed (n = 13) reported that remote sensing data was not used or only indirectly utilized. The 25% of respondents who indicated that they did use remote sensing data were mainly referring to the use of in-situ sensors such as stream and river flood gauges or the lahar monitors that are in place on the Cascade volcanoes. After summarizing the goals of the SPURS-EM project and discussing remote sensing technologies, about 70% of those interviewed felt that remote sensing had a "significant" potential in the operations of EMD.

In summary, at the start of the SPURS-EM project EMD staff and management did not have a working knowledge of remote sensing, but they were anticipating that an ability to better utilize remote sensing data would enhance EMD operations. In hindsight it is also clear that most EMD staff, as well as some technical consultants working on the SPURS-EM team, did not fully understand the technical basis and limitations of adaptive landcover

[1] HAZUS, which stands for Hazards U.S., is an earthquake loss-estimation modeling software that was developed by FEMA.

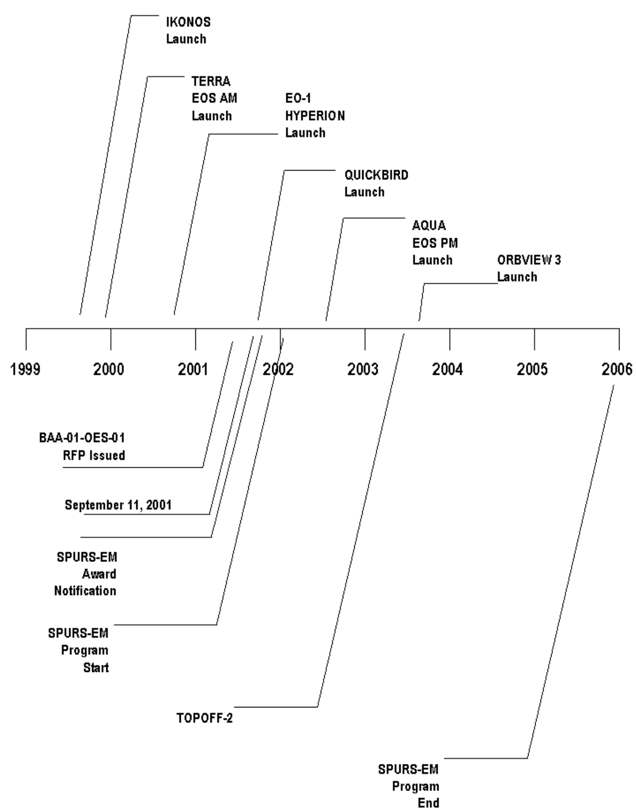
classification technology. During the first year of the project a significant effort was made to cross educate the SPURS-EM team. The importance of this cross-training phase of the project cannot be over emphasized.

The SPURS-EM goal of providing "more current remotely sensed information to support the hazards analyses and predictive functions of EMD in developing the Strategic Forecast Support System" was only partially realized. Perhaps the most significant outcome derived from the SPURS-EM project was that EMD hired a person trained in remote sensing technology and now maintains a capability to process, analyze and display remote sensing data derived from almost any source.

<u>SPURS-EM: Working in The Face of Industry Change</u>

The SPURS-EM project started in early 2002 shortly after the events of September 11, 2001 transformed the U.S. emergency management community. The project also began amidst a four year period when remote sensing was entering a new technological era (Figure 26).

Figure 26: SPURS-EM Timeline



Source: Western Disaster Center (2005)

From 1999 until 2003, NASA successfully launched the core components of the Earth Observing System (EOS) with the Terra, Aqua and Hyperion satellites. During this same time period the commercial remote sensing industry was revolutionized with the launch of the first high-resolution commercial satellite imaging systems: IKONOS, QUICKBIRD and ORBIMAGE 3 satellites.

Policy was also evolving during this period. Studies like the 1996 National Research Council report "Computing and Communications in the Extreme" concluded that preparing for and responding to crises places demands on Information Technology that cannot be satisfied readily with existing tools, products, and services. The 1997 Disaster Information Task Force report "Harnessing Information and Technology for Disaster Management" went further to conclude that disaster related loss of life could be reduced and property losses could be significantly lessened if effective use were made of all-source data collection and information resources and evolving computer and communication technologies, and recommended that a US Disaster Information Network be established. The 1999 National Research Council report "Reducing Disaster Losses through Better Information" concluded that there can be no justification for continuing in the current mode of non-standard disparate resources (e.g. hardware, software, tools and services) when available modern technological developments make their linkage a relatively straightforward matter with obvious potential payoffs in saving lives and reducing losses. The advances in computer and information technologies combined with the capabilities provided by the NASA Earth Observing System (EOS), and commercial high resolution remote sensing satellite companies, were the underlying technological drivers for these shifts in policy towards more proactive and technology-driven emergency management capabilities.

One of NASA's stated reasons in 2001 for funding the SPURS-EM effort was to advance the process by which geospatial information could be utilized to improve decision-making and policy formulation in the operations of state, local, regional and tribal governments (BAA-01-OES-01). At the end of the SPURS-EM project in 2005 the state-of-the-art has evolved to the point that serious concerns are now being raised on how to limit public access to high resolution geospatial products.

Today's web-based mapping products such as the Google Map search tool that overlays high resolution imagery onto street maps, and the Google Earth software that allows a user to do complex image manipulation like image zoom and perspective rotations in real-time, has placed advanced geospatial tools into the hands of the average Internet user. No TV newscast is complete without a high resolution satellite image depicting the most current disaster.

Under the appropriate cautions, these public geospatial data resources can be used by the emergency management community. However, in critical disaster situations, where lives are at stake, and billions of dollars in property may be at-risk, it would not be appropriate to depend solely on these public data sources. One of the lessons learned indirectly during the SPURS-EM project is that there can be a significant risk of un-met expectations if the emergency management community becomes too reliant on public or commercial data sources that might not be available in a crisis situation.

What the Future Holds

The most significant impediment to the incorporation of advanced geospatial technologies into the emergency management mission is the lack of resources in the typical emergency management organization and an operational national protocol addressing the specific remote sensing needs of the emergency management community. Issues are further complicated because most of those trying to promote advanced geospatial technologies think of the emergency management community as being analogous to the military. Marketing efforts and technology demonstrations seem to emphasize the new commercial high-resolution imaging satellites. Although satellites can provide synoptic coverage that is ideal for the planning and recovery phases of a disaster they are not timely enough to effectively support the response phase. Satellite imagery is also expensive and most states, including Washington, do not have any process in place where they can easily order and receive these data during a crisis situation. Other developers are proposing using Unmanned Aerial Vehicles (UAV) in the emergency management mission. In the military the complications of using unmanned vehicles is justified because they can save lives of pilots in hostile environments. In the public sector UAVs are simply not practical. There are still serious operational limitations on where a UAV can fly in controlled airspace, and there is little that justifies using a UAV in an emergency management situation instead of a manned aircraft. Even the military has now concluded that UAVs are not cost-effective, and may be more costly to operate than manned aircraft (Space News, September 12, 2005, "Unpiloted Aircraft Do Not Save Money, Studies Find").

The 1997 Disaster Information Task Force report "Harnessing Information and Technology for Disaster Management" recommended that the Intelligence Community develop a sustainable plan for timely access to classified data and derived products for the U.S. Disaster Management community, a goal that has yet to be been achieved. For example, during the TOPOFF2 Exercise in 2003 in Seattle, EMD requested access to unclassified image-derived products to support their planning activities, and more importantly to prototype an operational relationship with the National Imagery and Mapping Agency (NIMA) - now the

National Geospatial Intelligence Agency (NGA). This request was made months before the TOPOFF 2 Exercise started, and was coordinated through FEMA Region X. EMD was never notified of any decisions and nothing became of the request. NGA now seems to be making some progress in coordinating the sharing of remote sensing products. The USGS in partnership with NGA is working with some emergency management organizations to establish regional "Homeland Security Imagery Data Servers". Ideally these activities will lead to a workable national protocol.

In summary, the state of the Emergency Management and Remote Sensing disciplines at the start of the SPURS-EM project were very much in a state of flux. Many challenges remain in the effort to integrate aspects of these disciplines to reduce the impact of natural and man-made hazards to people, property, economy, and the environment. Central to overcoming these issues will be the development of cost-effective imagery, rapid response imagery, and improved communications between the public and private sectors. In the meantime, EMD will continue to develop its GIS Program and be prepared to adopt SRS as soon as it is feasible.

CONCLUSIONS AND RECOMMENDATIONS

The SPURS-EM project was the first of its kind to be undertaken by the Washington Emergency Management Division. The experiences and lessons learned through this effort have resulted in many significant changes, some of which will have long-lasting effects. Through the SPURS-EM project we found that:

- The greatest challenges in the integration of SRS data products into emergency management are: timeliness of data, spatial resolution, processing requirements, and lack of expertise in remote sensing.
- The use of moderate-resolution SRS data in hazard analysis is not practical due to a combination of the factors listed above.
- High-resolution data is strategic, but not practical due to timeliness and cost.
- Ecoregions are valuable in the analysis of regional ecosystems, but lack effectiveness in emergency management planning.

Based upon these conclusions, EMD considered the range of data, tools, and services that could be provided by the remote sensing community to increase the practicality of integrating SRS in emergency management. EMD provides the following recommendations to the remote sensing community:

- Enhance the understanding of remote sensing in the emergency management community by providing access to user-friendly education and outreach opportunities.
- Provide more timely access to data products and expert interpretations. Data products must be available at little/no cost, and be easily interpretable by decision-makers who have little/no background in image analysis.
- Reduce processing requirements for data products. The process of ordering, downloading, projecting, resampling, and scaling imagery to meet user needs is cumbersome and time-intensive. Providing users with more options for acquiring data in desired formats and extents would reduce the costs of data processing.
- Improve integration with industry leading software (e.g. ESRI, ERDAS). The remote sensing community should work with industry-leading software providers to ensure that software packages are designed to handle a wide range of data products, while remaining user-friendly.
- Develop more emergency management-specific applications that utilize SRS data. The MODIS Rapid Response Tool and GeoMac are excellent

examples of applications that were designed with the needs of emergency managers in mind.

- Formalize a national protocol for data sharing among government agencies, the private sector, and academia. The sharing of data across sectors and disciplines is essential in order to maximize the value of available SRS products.

In considering these recommendations, NASA and other remote sensing agencies and organizations should bear in mind the information needs of the emergency management community. Throughout the SPURS-EM project, our team consistently focused on the needs of our colleagues and constituents in order to develop more effective and meaningful products. Through interaction with emergency managers at the federal, state, and local levels, we conclude that the following represent those characteristics of SRS that emergency managers consider the most desirable:

- Near-real-time
- High-resolution
- True-color
- Emergency Management-specific applications (e.g. GeoMac)

In conclusion, EMD is grateful for the opportunity to work with NASA and our colleagues in academia, and the public and private sectors that helped make the SPURS-EM project such a success. We look forward to participating in future endeavors with our new partners and anxiously await the development of new and innovative remote sensing tools and services that will serve the emergency management community and EMD in our mission to protect the people, property, economy, and environment of Washington State.

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(Space News, September 12, 2005, “Unpiloted Aircraft Do Not Save Money, Studies Find”).

APPENDICES

Appendix A: Budget Summary

NASA Grant Proposal				
2002	2003	2004	2005	TOTAL
$324,500	$237,000	$139,305		$700,805

EMD Matching Proposal				
2002	2003	2004	2005	TOTAL
$105,000	$137,500	$139,794		$382,294

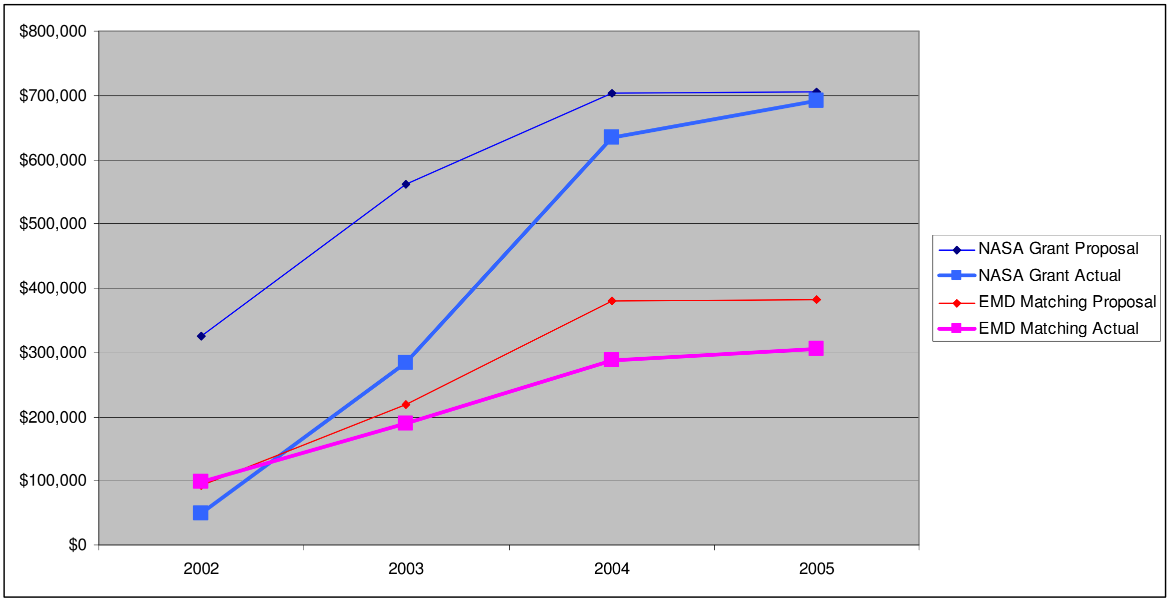
Proposed Totals				
2002	2003	2004	2005	TOTAL
$429,500	$374,500	$279,099		$1,083,099

NASA Grant Actual				
2002	2003	2004	2005	TOTAL
$48,573	$234,891	$351,468	$	$705,805

EMD Matching Actual				
2002	2003	2004	2005	TOTAL
$98,715	$91,368	$97,487		

Actual Totals				
2002	2003	2004	2005	TOTAL
$147,288	$326,259	$448,995		

Figure 27: Budget Summary



Source: Allen Jakobitz (EMD)

<u>2002 Budget Summary</u>
got off to a slow start. The grant arrived later than expected. EMD approval process took longer than expected. The University of Washington's invoicing was slow to get started.
$147,288 – Organized teams; staffed; equipped; initiated research; EMD RS training at UW

<u>2003 Budget Summary</u>
2003 & 2004 saw the spending levels increase as the bulk of the research activities occurred. $326,259 – Considerably research; Collected data; Developed outreach;\

2004 Budget Summary
2003 & 2004 saw the spending levels increase as the bulk of the research activities occurred. $448,955 – Completed data collection; Completed research; Integrated RS into MHAR; Investigated web delivery.

<u>2005 Budget Summary</u>
2005 spending leveled off as the project concluded. $160,596 – Deliberated level of integration; Wrote final report. Total expended = 1,083,099

Appendix B: Communications

STATE OF WASHINGTON

OFFICE OF THE GOVERNOR

P.O. Box 40002 • Olympia, Washington 98504-0002 • (360) 753-6780 • TTY/TDD (360) 753-6466

October 20, 2005

NASA Headquarters
Office of the Administrator
Administrator Michael Griffin, Ph.D.
300 E Street SW
Washington, DC 20545-0001

Dear Administrator Griffin:

On January 17, 2002, NASA awarded the Washington Military Department's Emergency Management Division (EMD) a grant (# NAG13-02019, implemented through Applied Sciences at Stennis Space Center) for the "Strategic and Practical Use of Remote Sensing in Emergency Management (SPURS-EM)". As this project comes to a close, I am moved to express our gratitude because the citizens of Washington State received tremendous benefits as a result of your support.

The SPURS-EM project conducted applied research into the practical use of NASA-supplied remotely sensed satellite data in Washington State Emergency Management operations. In meeting the objectives of the project, EMD staff significantly increased the use of science-based hazard analysis and now have a good understanding of remotely sensed satellite data and its applicability to emergency management. As a direct result of the project, we developed an extensive Geo-spatial Information System which is an exciting new tool that is now used in virtually every emergency management activity.

EMD also uses technical applications, databases, remotely sensed data and imagery for daily activities. These activities include, Mount Saint Helens ash-fall plume modeling, wildfire identification and tracking, and the use of computer models to estimate the effects of hazards. In the near future, EMD will develop an integrated hazard and critical infrastructure map supporting the State Homeland Security Strategy.

As a direct result of the grant, I consider Washington State citizens more secure from the effects of natural and human-caused disasters. My staff appreciated the opportunity to participate in NASA's program of partnerships with State, Local and Tribal jurisdictions and I hope that NASA will continue these programs and bring the benefits of earth observing satellites and applied science to the citizens of my State and our Nation.

Sincerely,

Christine O. Gregoire
Governor

GARY LOCKE
Governor

STATE OF WASHINGTON
OFFICE OF THE GOVERNOR
P.O. Box 40002 • Olympia, Washington 98504-0002 • (360) 753-6780 • TTY/TDD (360) 753-6466

July 10, 2001

Mr. Chuck Hutchinson
Acting Director
Applications Division
National Aeronautics and Space Administration
Washington, D.C. 20546-0001

Dear Mr. Hutchison:

I am pleased to offer my strong support for the grant proposal submitted to you by the Emergency Management Division (EMD) of the Washington State Military Department, in partnership with the University of Washington and the Western Disaster Center.

EMD is committed to improving our state's ability to integrate remotely sensed data into its operational structure and decision-making processes. During the aftermath of the Nisqually earthquake on February 28, 2001, I observed firsthand how EMD currently uses GIS (Geographical Information System) information. Within an hour of the event, EMD made a loss prediction based upon a model used in HAZUS (Hazard US), a GIS product provided by the Federal Emergency Management Agency. This model was helpful to me in making a decision to proclaim a state of emergency in the state of Washington. Twenty-four hours later, President Bush declared a federal emergency, based upon the recommendation of the HAZUS model.

I fully support the collaboration of the Emergency Management Division with the University of Washington and the Western Disaster Center. This strategic alliance taps into the strengths of each organization and ensures that the products and procedures that are developed will be shared on a regional and national basis with our partners in emergency management.

I request your favorable consideration of this grant proposal.

Sincerely,

Gary Locke
Governor